IDAHO FISH & GAME

CAPTIVE REARING PROGRAM FOR SALMON RIVER CHINOOK SALMON

Annual Progress Report
Report Period January 1, 2002 to December 31, 2002

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Captive Rearing Program for Salmon River Chinook Salmon

Project Progress Report

2002 Annual Report

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ABSTRACT

During 2002, the Idaho Department of Fish and Game continued to develop techniques to rear Chinook salmon *Oncorhynchus tshawytscha* to sexual maturity in captivity and to monitor their reproductive performance under natural conditions. Eyed-eggs were hydraulically collected from redds in the East Fork Salmon River (EFSR; N = 328) and the West Fork Yankee Fork Salmon River (WFYF; N = 308) to establish brood year 2002 culture cohorts. The eyed-eggs were incubated and reared at the Eagle Fish Hatchery, Eagle, Idaho (Eagle). Juveniles collected in 2000 were PIT and elastomer tagged and vaccinated against vibrio *Vibrio* spp. and bacterial kidney disease prior to being transferred to the NOAA Fisheries, Manchester Marine Experimental Station, Manchester, Washington (Manchester) for saltwater rearing through maturity. Smolt transfers included 203 individuals from the WFYF and 379 from the EFSR. Maturing fish transfers from Manchester to Eagle included 107 individuals from the LEM, 167 from the WFYF, and 82 from the EFSR. This was the second year maturing adults were held on chilled water at Eagle to test if water temperature manipulations could advance spawn timing. Adults from the LEM and WFYF were divided into chilled ($\approx 9°C$) and ambient ($\approx 13.5°C$) temperature groups while at Eagle. Forty-seven mature females from the LEM (19 chilled, 16 ambient, and 12 ambient not included in the temperature study) were spawned at Eagle with 42 males in 2002. Water temperature group was not shown to affect the spawn timing of these females, but males did mature earlier. Egg survival to the eyed stage averaged 66.5% and did not differ significantly between the temperature groups. Personnel from the Shoshone-Bannock Tribe placed a total of 47,977 eyed-eggs from these crosses in in-stream incubators. Mature adults (N = 215 including 56 precocial males) were released into the WFYF to evaluate their reproductive performance. After release, fish distributed themselves throughout the study section and displayed a progression of habitat associations and behavior consistent with progressing maturation and the onset of spawning. Twenty-six captive-reared females constructed 33 redds in the WFYF in 2002. Eighteen of these were hydraulically sampled, and eggs were collected from 17. The percentage of live eggs ranged from 0–100% and averaged 34.6%. No live eggs were found in redds spawned by brood year 1997 females. Expanding these results to the remaining redds gives an estimate of 22,900 eyed-eggs being produced by captive-reared fish in the WFYF. Additionally, 130 mature adults (including 41 precocial males) were released into the EFSR. Almost all of these fish moved out of the areas shoreline observers had access to, so no spawning behavior was observed. Radio-telemetry indicated that most of these fish initially moved downstream (although three females moved upstream as far as 7 km) and then held position.

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INTRODUCTION

Idaho Department of Fish and Game's (IDFG) long-term management objective for Chinook salmon *Oncorhynchus tshawytscha* is to maintain Snake River salmon populations at levels that will provide sustainable harvest (IDFG 1996). Restoring currently depressed populations to historic levels is a prerequisite to this condition. Artificial propagation of spring and summer Chinook salmon in the Salmon River basin, through Lower Snake River Compensation Plan (LSRCP) and Idaho Power Company hatcheries, was initiated to compensate for lost production and productivity caused by the construction and operation of private and federal hydroelectric facilities in the Snake River basin. The mitigation approach was to trap, spawn, and rear a portion of the historically productive local broodstock to produce a large number of smolts (Bowles 1993). When Chinook salmon trapping began in 1981 as part of the LSRCP, it was assumed that enough Chinook salmon adults would return to provide for harvest and continued hatchery production needs. It was also assumed that hatchery programs would not negatively affect the productivity or genetic viability of target or other populations and that natural populations would remain self-sustaining even with hydropower projects in place. In reality, smolt to adult survival in wild Snake River Chinook salmon declined abruptly with completion of the federal hydroelectric system by the mid-1970s (Petrosky and Schaller 1994; Petrosky et al. 1999), and numbers of naturally produced salmon declined at various rates throughout the Snake River basin. It now appears the survival rate estimates used in the hatchery mitigation program models were substantially overestimated, which has led to hatchery programs that have been unable to mitigate for the loss of Chinook salmon due to hydroelectric facilities or stem the decline of target populations. Spring/summer Chinook salmon returns have been insufficient to meet artificial and natural smolt and adult production predictions, much less provide a consistent harvestable surplus of adults (Hassemer 1998).

Development of the Snake River hydrosystem has substantially influenced the decline of local spring/summer Chinook salmon stocks by reducing productivity and survival (Raymond 1979; Schaller et al. 1999) and has contributed to the listing of Snake River Chinook salmon under the Endangered Species Act (ESA; NMFS 1992). A recovery strategy incorporating natural-river function is most likely to increase the smolt-to-adult return rate and provide for recovery of these populations (Marmorek et al. 1998). However, until smolt-to-adult survival is increased, our challenge is to preserve the existing metapopulation structure (by preventing local or demographic extinctions) of these stocks to ensure they remain extant to benefit from future recovery actions. This project is developing technology that may be used in the recovery of the listed Snake River spring/summer Chinook salmon evolutionarily significant unit (ESU), which consists of 38 subpopulations (i.e., breeding units or stocks; NMFS 1995). Preserving the metapopulation structure of this ESU is consistent with the predecisional Snake River Salmon Recovery Plans (NMFS 1995; Schmitten et al. 1997), and supports the Northwest Power Planning Council's goal of maintaining biological diversity while doubling salmon and steelhead runs (NPPC 1994).

Idaho and Oregon state, tribal, and federal fish managers met during 1993 and 1994 to discuss captive culture research and implementation in the Snake River basin. The outcome of those meetings was an agreement that the Oregon Department of Fish and Wildlife would initiate a captive broodstock program using selected Grande Ronde River Chinook salmon populations, and the IDFG would initiate captive rearing research using selected Salmon River Chinook salmon populations. Both captive culture techniques begin by bringing naturally produced juveniles (eggs, parr, or smolts) into captivity and rearing them in a hatchery to sexual maturity. At this point the two techniques diverge. The F_1 generation in a captive rearing

program are returned to their natal stream and allowed to spawn naturally. The F_1 generation from a captive broodstock program is spawned in the hatchery, where the resulting F_2 progeny are held until smoltification. The F_2 generation smolts are then released to their natal streams to emigrate volitionally. The primary focus of these programs was to evaluate the effectiveness of the two forms of captive culture to meet population conservation objectives. Implicit within each research project was the objective to develop and test appropriate facilities and fish culture protocols specific to the captive culture of Chinook salmon for conservation management of depressed populations.

Little scientific information regarding captive culture techniques for Pacific salmonids was available at the inception of these programs, but a substantial amount of new literature has been published in the ensuing years. The Chinook Salmon Captive Propagation Technical Oversight Committee (CSCPTOC) was formed to convey this new information between the various state, federal, and tribal entities involved in the captive culture of Chinook salmon. The CSCPTOC meets approximately every two months, which allows an adaptive management approach to all phases of the program and provides a forum of peer review and discussion for all activities and culture protocols associated with this program. Flagg and Mahnken (1995) provided an initial literature review of captive rearing and captive broodstock technology, which provided the knowledge base the program was designed upon. Using this work, the IDFG captive rearing program for Salmon River Chinook salmon was initiated to further the development of this technology by monitoring and evaluating captive-reared fish during rearing and post-release spawning phases. Since the program's inception, studies documenting the spawning behavior of captively reared Chinook salmon (Berejikian et al. 2001b), coho salmon *O. kisutch* (Berejikian et al. 1997), and Atlantic salmon *Salmo salar* (Flemming et al. 1996) have been published. Other studies have also compared the competitive behavior of male captive-reared and wild coho salmon during spawning (Berejikian et al. 2001a) and the competitive differences between newly emerged fry produced by captive-reared and wild coho salmon (Berejikian et al 1999). Finally, Hendry et al. (2000) report on the reproductive development of sockeye salmon *O. nerka* reared in captivity.

The IDFG captive rearing program was developed as a way to increase the number of breeding units and maintain metapopulation structure in selected populations at high risk of extinction while avoiding the impacts of multigenerational hatchery culture described in Reisenbichler and Rubin (1999). The strategy of captive rearing is to prevent cohort collapse in the target populations by returning captive-reared adults to natural spawning areas to augment depressed natural escapement (or replace it in years when no natural escapement occurs). This maintains the continuum of generation-to-generation smolt production and provides the opportunity for population maintenance or increase should environmental conditions prove favorable for that cohort. However, this number remains somewhat speculative because of uncertainties associated with the ability of the captive rearing approach to produce adults with the desired morphological, physiological, and behavioral attributes to successfully spawn in the wild (Fleming and Gross 1992, 1993; Joyce et al. 1993; Flagg and Mahnken 1995).

The IDFG captive rearing program was initiated in 1995 with the collection of brood year 1994 Chinook salmon parr from three study streams. Since then, naturally spawned Chinook salmon progeny from brood years 1995-2002 have been represented in captivity to continue the project. Hassemer et al. (1999, 2001) and Venditti et al. (2002, 2003) summarize project activities from inception through 2001. The streams selected for inclusion in the captive rearing program include the Lemhi River (LEM), the East Fork Salmon River (EFSR), and the West Fork Yankee Fork Salmon River (WFYF; Figure 1). Water temperatures are ideal for juvenile Chinook salmon rearing in all three streams while water quality ranges from sufficient to ideal.

Habitat quality ranges from relatively pristine to areas of riparian degradation caused by sedimentation, grazing, mining, logging, road building, and irrigation diversion. The LEM drains productive basaltic parent material resulting in rapid fish growth. The lower section of this river flows through private land developed extensively for agriculture and grazing and typically reflects C channel conditions (Rosgen 1985). The EFSR drains a relatively sterile watershed of granitic parent material associated with the Idaho batholith. The lower 30 km of the EFSR runs through ranch and grazing property developed during the last century, but the upper reaches reflect near pristine conditions with little historical disturbance from logging, mining, or agriculture. Stream habitat in the EFSR typically reflects B and C conditions (Rosgen 1985). The WFYF, which drains a sterile watershed similar to the EFSR, remains primarily roadless and has remained nonimpacted by land use practices for nearly half a century. Stream habitat typically reflects B and C conditions (Rosgen 1985).
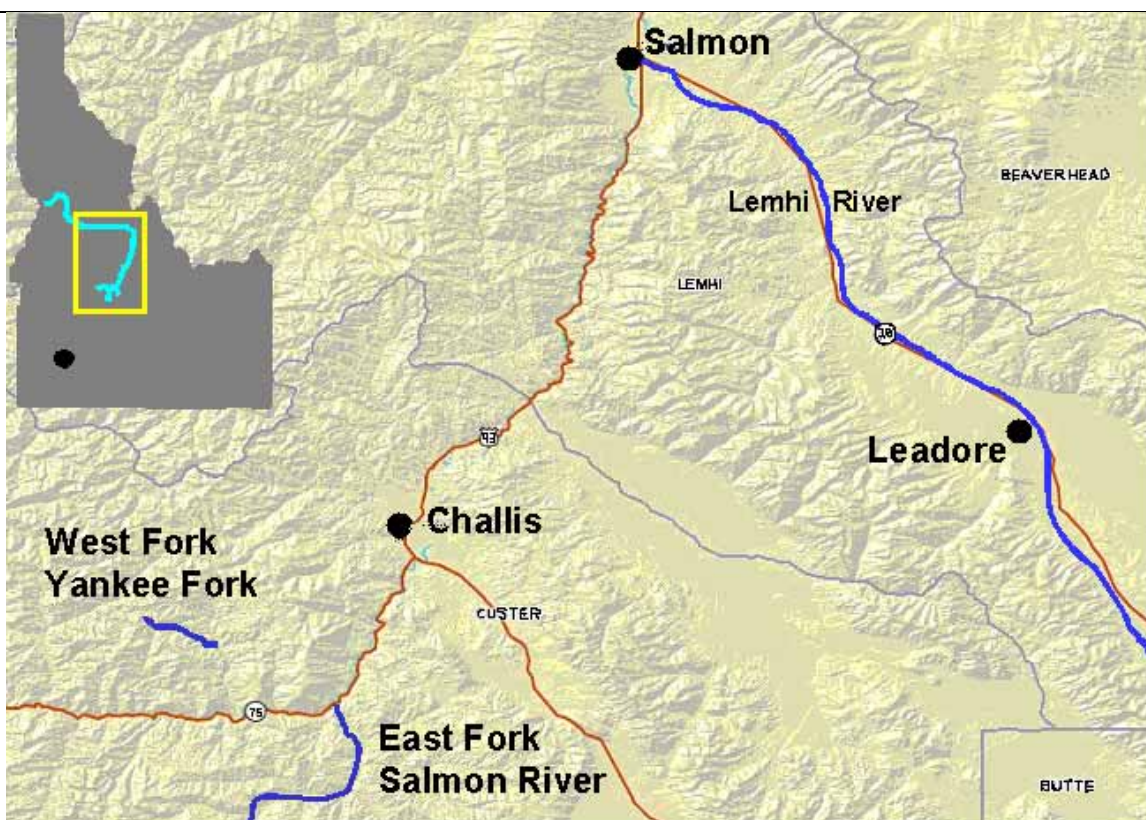
Figure 1.   Location of study streams included in the Idaho Department of Fish and Game Captive Rearing Program for Salmon River Chinook Salmon.

The goal of the captive rearing program is to evaluate the potential usefulness of the captive rearing concept as applied to the conservation of Snake River spring/summer Chinook salmon. We have identified two primary project objectives needed to realize this goal. These are to: 1) develop and implement culture practices and facility modifications necessary to rear Chinook salmon to adulthood in captivity having morphological, physiological, and behavioral characteristics similar to wild fish, and 2) evaluate the spawning behavior and success of captive-reared individuals under natural conditions. These objectives divide the program into

two functional units including fish culture and field evaluations, but the success of the program is dependent on the synchronous development of both. This report documents activities performed in both aspects of the evaluation from January 1, 2002 through December 31, 2002. This project is coordinated with the Northwest Power Planning Council's Fish and Wildlife Program (NPPC 2000) and is identified as project 0004002. Funding was provided through the Bonneville Power Administration under contract 1997-001-00.

METHODS

Culture Facilities

The IDFG Eagle Fish Hatchery (Eagle) is the primary Idaho site for the captive culture of program fish. The hatchery is supplied with pathogen-free artesian water from three wells, and the artesian flow is augmented with four separate pump and motor systems. Ambient water temperature and total dissolved gas average 13.5°C and 100% after degassing, respectively. Water chilling capability was added in 1994 and expanded in 2001 for use during various stages of the captive rearing process. Water temperature is maintained between 7.0°C and 9.0°C during the egg incubation period of the rearing cycle. From ponding through transfer of smolts to salt water, water temperature is maintained between 8.0°C and 10.0°C. Chilled water is also used in holding tanks of maturing, adult Chinook salmon prior to release for natural spawning. Backup and system redundancy is maintained for degassing, pumping, and power generation. Nine water level alarms are linked through an emergency service operator. Additional security is provided by limiting public access and by the presence of three on-site residences occupied by IDFG hatchery personnel.

Tanks of various sizes and configurations are maintained at Eagle to accommodate the various life stages and sizes of Chinook salmon maintained on station. Plastic incubators and fiberglass tanks ranging in size from 0.7–6.0 m in diameter are used to culture Chinook salmon from eggs to maturity. Fertilized eggs are held in incubators until swim-up and then transferred to 0.7 m semisquare tanks (0.09 m^3) and then to 1.0 m diameter semisquare tanks (0.30 m^3) where they remain until they reach approximately 1 g. They are then moved to 2.0 m semisquare tanks (1.42 m^3) where they remain until reaching about 20 g and then to 3.0 m circular tanks (6.50 m^3) where they remain until age-3 (approximately 1,000 g). Finally, the age-3 fish are transferred to 6.0 m circular tanks (44.5 m^3) where they remain until maturity. Fish transfers between tanks are density related; fish are divided into multiple tanks and/or moved to larger tanks when densities reach 8 kg/m^3. Maturing fish are held in 3.0 m circular tanks, by stream origin, until they are released into their natal waters or spawned in the hatchery. Hatchery spawnings are utilized to monitor gamete quality and to supply safety net Chinook salmon when natural production is not sufficient for natural egg sourcing. Flow to all tanks is maintained at no less than 1.5 exchanges per hour, and shade covering (70%) and jump screens are used where appropriate. Tank discharge standpipes are assembled in two sections ("half pipe principle") to prevent tank dewatering when removed for tank cleaning.

Tanks and culture facilities utilized by the Chinook salmon captive rearing program are located in three general areas at Eagle. Spawning, incubation, and fry rearing take place in an enclosed building plumbed with chilled and ambient water, which allows water temperature regulation through controlled mixing. The intermediate sized tanks are located adjacent to the spawn building and also receive both chilled and ambient water. A roof covers tanks in this location, but the sides are not walled. The third group of tanks used by this project is located in

a different area of the hatchery grounds, approximately 100 m from the incubation building. The 3.0 and 6.0 m tanks are housed in this group and are shielded from avian predators by a wire mesh enclosure. Additionally, a metal roof is in place over the 6.0 m tanks to provide shade covering, but the 3.0 m tanks are exposed to direct overhead and peripheral sunlight. A second water chiller was installed in 2001 to provide water temperature control to two of the 3.0 m tanks in this group; the other tanks receive ambient temperature water only.

Fish husbandry practices employed at the Eagle facility range from traditional to experimental. Fish health issues are handled using only approved therapeutants, and standard fish culture practices are employed whenever possible (for an overview of standard methods see Leitritz and Lewis 1976; Piper et al. 1982; Erdahl 1994; Bromage and Roberts 1995; McDaniel et al. 1994; Pennell and Barton 1996). However, due to the experimental nature of the work conducted at Eagle, some aspects of the incubation, rearing, and feeding protocols differed from those used at production hatcheries. Eggs are hatched in specially designed incubators that allow siblings from individual spawn crosses or redds to be maintained separately, and this separation is maintained until after Passive Integrated Transponder (PIT) tagging (Prentice et al. 1990) to permit future familial identification. Rearing tank size, density, and food ration vary with fish age, and are managed to promote optimum growth and the attainment of program objectives. Juveniles are periodically anesthetized, weighed to the nearest 0.1 g, and measured to the nearest 1 mm fork length (FL) to track growth and to ensure that projected weights tracked closely with actual weights.

Fish are fed a standard commercial diet produced by Bio-Oregon, Inc. (Warrenton, Oregon) until they reach approximately 160.0 g, after which time they receive a special brood diet enhanced with natural flavors from fish and krill. Diet ration and water temperature are manipulated to simulate the ration and temperature regimes that would be experienced in the natural environment to modulate growth and reduce precocial male development. This feeding regime has been developed collaboratively with NOAA Fisheries (Project Number 199606700).

Saltwater rearing is provided for the majority of study animals post smoltification at the NOAA Fisheries Manchester Marine Experimental Station (Manchester, Washington; Manchester). This facility is located on Puget Sound near Seattle, Washington and is supplied with approximately 5,000 L/min of saltwater that ranges in temperature between 7°C and 14°C annually and averages $29^0/_{00}$ salinity. Raw saltwater is passed through sand and cartridge filters to remove particles >5 μ, sanitized with ultraviolet light, and degassed prior to entering fish rearing tanks. Effluent from the rearing tanks is sanitized with ozone treatment prior to being returned to Puget Sound (Frost et al. 2002).

Eyed-Egg Collection, Incubation, and Transport

Eyed-eggs to establish brood year 2002 captive cohorts were collected from redds spawned by wild Chinook salmon in the WFYF and the EFSR using hydraulic sampling methods described by McNeil (1964). The hydraulic sampling system consists of two main components. The first is a gas-powered pump attached to a 3.8 cm diameter aluminum probe via flexible tubing (Figure 2A). Holes drilled near the top of the probe infuse air into the water stream through venturi action. The second component is the collection net frame consisting of a "D" shaped aluminum frame with expanded plastic mesh along its curved portion and netting around the bottom and sides of its straight portion (Figure 2B). During operation, water is forced through the probe, which is worked into the substrate. The air/water stream then lifts eggs out of the substrate, where they are swept downstream into the net. The expanded plastic screen confines

eggs lifted out near the periphery and channels them into the net. In order to minimize disturbance to the redd, sampling is generally begun slightly below estimated nest pocket locations and progresses upstream. This procedure prevents the fine materials lifted out of the substrate from settling back into the redd and possibly smothering the eggs. Care is also taken to keep personnel behind or to the side of the net frame to minimize redd trampling, which can kill eggs and pre-emergent fry in trout redds (Roberts and White 1992).
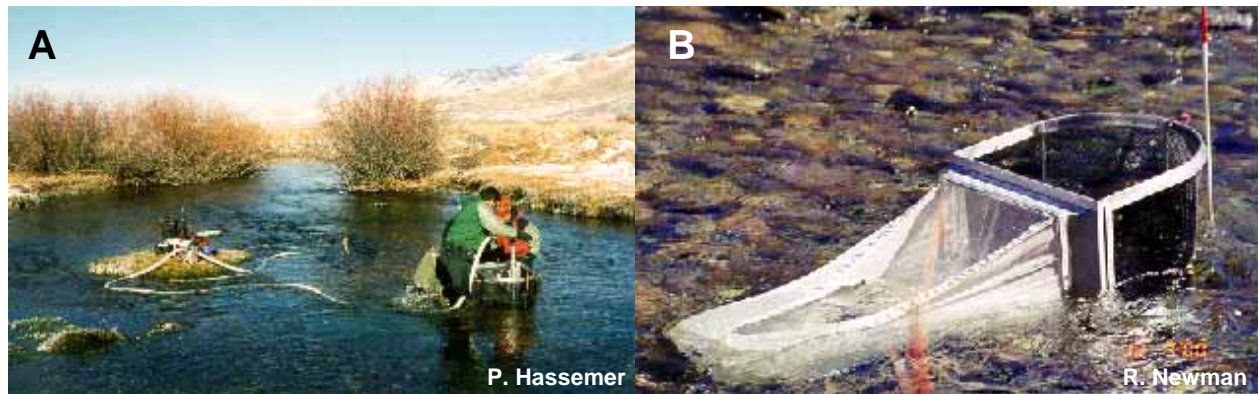
Figure 2.   Hydraulic sampling gear including (A) the pump and probe, and (B) the collection net used to collect eyed-eggs from naturally spawned redds.

To facilitate eyed-egg collections, redd locations are marked, construction and completion dates determined, and stream temperatures monitored with recording thermographs. Program personnel walk the WFYF from its confluence with the Yankee Fork Salmon River to our blocking weir and two sections of the EFSR every 7–10 d to identify new redds and estimate completion dates of redds located previously. Redd locations are marked by placing orange flagging on shoreline vegetation near their position. Information on when the redd was first observed and the spawning state of fish seen associated with the redd (i.e. courting, digging, trenching, etc.) is recorded on the flagging. Thermographs deployed in the study streams record water temperature every 2 h in the WFYF and EFSR, and daily average water temperature is computed to track the number of Celsius temperature units (CTUs) received by the developing embryos in each stream. Eyed-eggs are collected after receiving 300-400 CTUs. During this period, eye pigmentation makes developing embryos readily identifiable, and egg structures are capable of withstanding collection.

Eyed-eggs are transferred from collection locations to Eagle using the following standardized protocols. Eyed-eggs are packed at a conservative density in perforated shipping tubes, capped, and labeled to identify them to stream and redd. Tubes are wrapped in paper towels saturated with river water and packed in small, insulated coolers. Ice chips are added to maintain proper temperature and a moist environment during transport. Eggs are taken to Eagle as soon as possible after collection and are generally on site 4–6 h after extraction from the gravel.

Once at Eagle, familial groups of eyed-eggs are disinfected in 100 ppm Iodophor for 30 min. and transferred to separate incubators (14 cm diameter x 19 cm height, 2.5 L total operating volume) where they remain until the resulting fry are ready to begin feeding. A constant flow (2 L/min) of chilled water (approximately 10°C) is maintained throughout

incubation and is provided as upwelling from below the eggs (Figure 3A). Incubators are checked daily and dead eggs removed. After hatching, water flow is reversed to downwelling (Figure 3B).
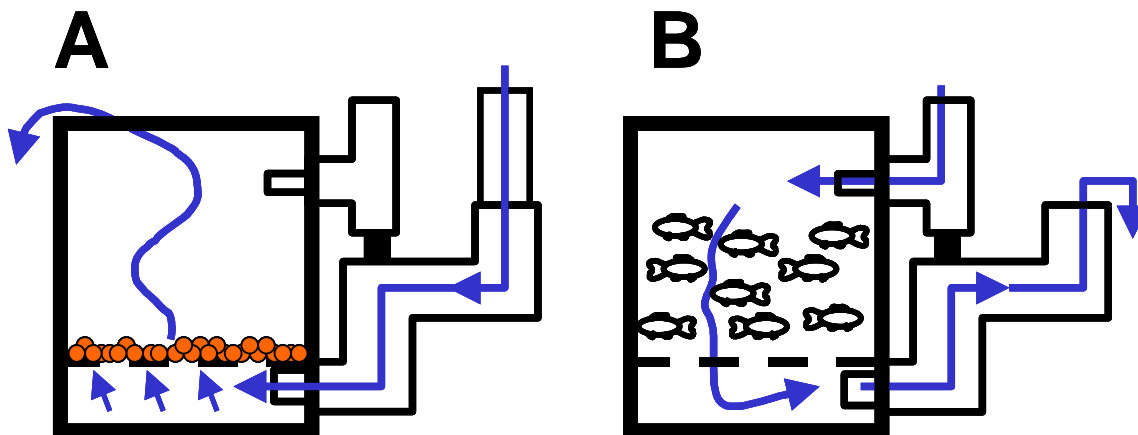
Figure 3.   Schematic diagram of reversible flow incubators used to incubate eggs and rear newly emerged fry. A) Upwelling configuration for egg incubation, and B) downwelling configuration for fry rearing.

Juvenile Rearing, Marking, and Transportation

Swim-up fry are fed for one week in their incubators prior to ponding to 0.7 m semisquare tanks, and individual family groups are maintained separately. Fry are fed hourly during daylight hours, approximately eight times per day, until they reach approximately 1 g. Growth projections are developed at this time, and feeding rates are reduced to four times per day. Tanks receive a mixture of ambient and chilled water that maintains a temperature of approximately 10°C and ensures approximately 1.5 turnovers/h. Fry are fed a commercial diet (Bio-Oregon, Inc. Starter #2) at approximately 2% body weight per day. As fish grow, ration and pellet size are adjusted accordingly. Sample counts are conducted as needed to ensure actual growth tracks the projected growth rate, but fish are handled as little as possible.

Juvenile Chinook salmon are marked during two separate events at Eagle each year to aid in tracking fish in the program. The first involves injecting a PIT tag into the peritoneal cavity of age-1 juveniles. Fish are anesthetized in MS-222 (tricaine methanesulfonate; buffered to neutrality with sodium bicarbonate), weighed to the nearest 0.1 g, and measured to the nearest 1 mm FL. A modified 12-gauge hypodermic needle is then used to inject the PIT tag into the body cavity slightly anterior to the pelvic girdle and just off the ventral midline. The PIT tag gives each individual a unique identity within the program that is used to track each fish through the remainder of its life. The second marking involves age-2 juveniles and is conducted shortly before they are transported to Manchester. Fish are again anesthetized in buffered MS-222, weighed to the nearest 0.1 g, measured to the nearest 1 mm, and a color-coded elastomer tag is injected into the clear tissue immediately posterior to the eye (Olsen and Vøllestad 2001; Close and Jones 2002), based on its stream of origin. Fish from the EFSR and WFYF receive

green and orange marks, respectively. The fish also receive interperitoneal injections of Renogen *Arthrobacter* spp. to vaccinate against bacterial kidney disease (BKD) and Vibrogen to vaccinate against *Vibrio* spp. After each marking event, fish are allowed to recover in coolers of fresh water, at the appropriate temperature, before being returned to the general population.

In contrast to previous years, all non-precocial age-2 (brood year 2000) juvenile Chinook salmon were transported to Manchester for saltwater rearing. Prior to transport, the juveniles were examined with a portable ultrasound machine to identify precocially developing males. Individuals determined to be maturing were retained at Eagle, and were released into their natal stream, used in hatchery spawn crosses, or had their milt cryopreserved. Non-maturing individuals were transported between facilities in truck-mounted insulated tanks (950 L capacity) with alarm and back-up oxygen systems on board, and "fresh flow" mechanical water movement units on board. Loading volumes did not exceed 89 kg/m^3. In addition, all vehicles had two-way radios and/or cellular telephones to provide routine or emergency communications. "Sentinel" groups of approximately 10 fish from each stock were transported to Manchester approximately one week in advance of the general population to verify the physiological readiness of the fish to tolerate saltwater. Prior to offloading, transport water was tempered to within 2.0°C of the receiving water, and fish were moved, by stock, to 6.0 m circular tanks filled with full strength freshwater for saltwater acclimation. Once in the circular tanks, full strength flowed into the tanks until the freshwater was completely replaced (approximately 12 h, C. McAuley, NOAA Fisheries, personal communication).

Brood year 2000 Yankee Fork Salmon River (YFSR) smolts were released into the YFSR to out-migrate volitionally. These fish were part of a one-time collection from that system that was made when it was felt by the CSCPTOC that there would not be sufficient natural escapement into the WFYF to support eyed-egg collections. This sampling event does not reflect a change in the scope or direction of the program. Sufficient escapement did occur, however, and we were able to source our culture group from the WFYF in that year. Additionally, genetic analysis indicated significant differences between fish from the two populations (M. Powell, University of Idaho, unpublished data). In light of this, it was determined by the CSCPTOC that releasing these fish as smolts would be the best course of action. Smolts were transported to the YFSR in truck mounted tanks (described above), loaded into insulated coolers, walked to the stream bank, and released into a long run near their site of collection.

Adult Rearing, Transportation, and Marking

Maturing Chinook salmon at Manchester are transported to Eagle to complete the freshwater phase of their maturation and for spawning performance evaluation. Maturation state is determined for all individuals at Manchester by ultrasound examination. A second maturation sort is also conducted at Manchester several weeks after the initial sort to identify any maturing fish not detected earlier. These fish are identified by visual observation and by physical manipulation of the gonads through the body wall. Adults are transported using similar equipment and techniques as described above, and loading volumes do not exceed 89 kg/m^3. Maturing fish from multiple brood years are pooled by stock for transport to Eagle, although stocks that may pose a health risk to other program fish are transported in separate vehicles. Tanks are loaded with two-thirds strength saltwater to begin freshwater acclimation during transport. Once at Eagle, fish are immediately placed in 3.0 m circular tanks filled with full strength freshwater.

Cohorts with potentially maturing fish at Eagle are examined, and maturing fish are taken out of the general population and removed from feed. Maturation sorts are conducted as early in the season as feasible, and maturation is determined by visual observation and by manipulating the gonads through the body wall. Maturing fish are moved into 3.0 m circular tanks and pooled, by stock, with those from Manchester.

All maturing adults from the WFYF and EFSR are fitted with disc tags, and a small number also receive a radio transmitter prior to their release for volitional spawning. Disc tags are color-coded to identify the temperature treatment (see below) and brood year the fish belonged to. Additionally, each disc tag has a unique number embossed upon it to identify the individual. Fish are anesthetized in a bath of buffered MS-222, weighed to the nearest 1.0 g, and measured to the nearest 1 mm FL. Water temperature in the anesthetic baths is determined by the temperature treatment the fish were being exposed to. Disc tags are attached to the fish by passing a stainless steel pin through a hole in the center of the tag and passing the pin through the musculature of the dorsal surface just ventral to the midline of the dorsal fin. Then, a corresponding tag (same color code and number) is slipped onto the pin on the opposite side of the fish. The tag is secured by trimming the pin to length, and a loop is formed at the end of the pin with needle-nose pliers. After receiving the disc tag, but before being allowed to recover from the anesthetic, a radio transmitter (Advanced Telemetry Systems model 5 or 10-28) is gastrically implanted via the esophagus following Burger et al. (1985) in a subgroup of the fish released. The external antenna is crimped at a position corresponding to the corner of the fish's mouth and allowed to trail along the side of the body. The size of fish receiving radio transmitters is compared to the general population with a two-sample t-test to verify those receiving the additional tag were representative of the entire population. After marking, fish are allowed to recover in coolers of temperature appropriate water before being returned to the holding tanks.

Chilled Water Experiments

A common thread linking previous releases of captive-reared Chinook salmon has been that these fish have consistently spawned several weeks later than their naturally produced counterparts (Hassemer et al. 1999, 2001; Venditti et al. 2002, 2003). In order to address this shortcoming, additional water chilling capacity was added at Eagle in 2001 to assess if water temperature manipulations between the time maturing adults were returned to freshwater and release could be used to advance their spawn timing. While we could find no instances where this has been tested on Chinook salmon, there is a substantial amount of literature describing the effect of temperature on the timing of ovulation in other salmonid species. Elevated holding temperature prior to spawning has been shown to retard the onset of ovulation in rainbow trout *O. mykiss* (Pankhurst et al. 1996; Pankhurst and Thomas 1998; Davies and Bromage 2002), pink salmon *O. gorbuscha* (Beacham and Murray 1988), Atlantic salmon (Taranger and Hansen 1993), and Arctic charr *Salvelinus alpinus* (Gillet 1991; Jobling et al. 1995). However, Henderson (1963) did not observe this relationship in eastern brook trout *S. fontinalis.*

Chinook salmon from brood years 1997, 1998, and 1999 from the WFYF and LEM stocks determined to be maturing were separated into three groups for holding at two temperatures during their freshwater maturation at Eagle. Fish determined to be maturing during the first maturation sort at Eagle and Manchester were separated into control and test groups. Control fish were maintained on ambient well water (≈ 13.5°C), and test fish were held on chilled water (≈ 8.9°C). A two-sample "t"-test was used to compare temperatures in the two sets of tanks. Care was taken to ensure that the entire size range of fish present was represented in

both groups. Mean group weights were calculated for each stock and brood year. Fish weighing less than the group average were randomly assigned to either the test or control group and were classified as small. Those weighing more than the group mean were also randomly divided between experimental groups and designated as large. The size classification was maintained throughout the study to determine if water temperature had a differential effect on spawn timing relative to body size. A two-sample *t*-test was used to verify that no differences existed in overall fish size in both groups and to evaluate differences in size classifications. A Chi-square analysis was used to compare the spawn timing of chilled and ambient group females spawned at Eagle or released to spawn volitionally. A third group of fish consisted of those determined to be maturing in the second maturation sort at Manchester. These fish (designated "late-arrivals") were held on ambient temperature water and were not included in the temperature experiment due to the different amount of time they spent in fresh water compared to the experimental groups. Statistical significance was assumed at α = 0.05.

Monitoring Programs

Hatchery Spawning and Gamete Evaluation

Fish from the LEM stock remained at Eagle and were spawned in the hatchery where the eggs remained through the eyed stage of development. In addition to the date fish from each group became ripe, hatchery spawning allowed us to compare a measure of egg quality (survival to the eyed stage) between the two temperature groups. This was important since elevated water temperature prior to ovulation has been shown to reduce egg survival in salmonids (Pankhurst et al. 1996; Taranger and Hansen 1993; Gillet 1991). When one or more females were determined to be in spawning condition, milt was preharvested from males with the same treatment history. Ripe females were stripped of their eggs and total fecundity was estimated by calculating average egg weight from a subsample of approximately 50 eggs and dividing the total egg weight by average egg weight. Eggs from each female were divided into one to three sublots of approximately equal size depending on the number of eggs produced. Each sublot was fertilized with milt from a unique male and placed in separate incubators (see Figure 3). The creation of multiple subfamilies increased the representation of parental genetic diversity in progeny groups. In addition, factorial-mating designs helped offset risks associated with individual incubator (sublot) loss and helped facilitate the identification of parents responsible for sublot failure. Incubators were checked daily and opaque eggs or those with fungal growth were removed. When the developing embryos had received approximately 325–350 CTUs, the eggs were shocked and those that became opaque were removed. Survival to the eyed stage was computed as the number of green eggs minus the number of dead or unfertilized eggs removed divided by the number of green eggs produced. Egg survival was compared between brood years and treatment groups using analysis of variance (ANOVA) to determine if these factors affected survival. The eyed-eggs were then provided to biologists with the Shoshone-Bannock Tribe who placed them in in-stream hatch-boxes within the LEM system.

Fish Health Monitoring

The captive rearing program utilizes disinfectants, antibiotics, vaccinations, and antifungal treatments to control pathogens. Dosage, purpose of use, and method of application for currently used drugs is as follows: 1) Antibiotic therapies: Erythromycin is administered orally, feeding medicated feed from Bio-Oregon, Inc. (Warrenton, Oregon) to produce a dose of

100 mg/kg of body-weight. Fish are fed medicated feed for up to a 28 d period to control BKD. When oral administration is not feasible, as with anadromous adults, an intraperitoneal injection of erythromycin is given at a dose of 20 mg/kg of body weight. Fingerlings are fed oxytetracycline or oxolinic acid medicated feed at a dose of 75 mg/kg of body weight for 10 d to control outbreaks of pathogenic aeromonads, pseudomonads, and myxobacteria, etc. as these cases arise. 2) Vaccinations: age-2 Chinook salmon are vaccinated prior to shipment to saltwater with intraperitoneal injections of Vibrogen (Aqua Health, Ltd., Charlottetown, PEI, Canada) to control *Vibrio spp.* and Renogen (Aqua Health Ltd.) to control BKD. 3) Egg disinfection: newly fertilized eggs are water hardened in 100 mg/L solution of Iodophor for 30 minutes to inactivate viral and/or bacterial pathogens on the egg surface and in the perivitelline space.

Fish health is checked daily by observing feeding response, external condition, and behavior of fish in each tank as initial indicators of developing problems. In particular, fish culturists look for signs of lethargy, spiral swimming, side swimming, jumping, flashing, unusual respiratory activity, body surface abnormalities, and unusual coloration. Presence of any of these behaviors or conditions is immediately reported to the program fish pathologist. When a treatable pathogen is either detected or suspected, the program fish pathologist prescribes appropriate prophylactic and therapeutic drugs to control the problem. Dead fish are routinely analyzed for common bacterial and viral pathogens (e.g., BKD, infectious hematopoietic necrosis virus, etc.). Select carcasses may be appropriately preserved for pathology, genetic, and other analyses. After necropsy, carcasses that are not vital to further analysis are disposed of as per language contained in the ESA Section 10 permit for the program.

Tissue samples are collected from dead program fish during necropsies to monitor for the presence of common bacterial and viral pathogens. American Fisheries Society "Bluebook" procedures are employed to isolate bacterial or viral pathogens and to identify parasite etiology (Thoesen 1994). All examinations are conducted under the direction of the program fish pathologist. Genetic samples are also collected from these fish in the event they may be needed in future mitochondrial DNA and/or nuclear DNA evaluations for Chinook salmon populations held in the program.

Spawning adults are analyzed for common bacterial and viral pathogens such as BKD, infectious hematopoietic necrosis virus, and viral hemorrhagic septicemia. Tissue samples are collected from the kidney, spleen, and pyloric caeca of each fish, and ovarian fluid samples are collected from each female and analyzed at the Eagle Fish Health Laboratory. In addition, tissue from maturing Chinook salmon transferred to the State of Idaho from Manchester are screened for *Piscirickettsia salmonis*, and additional ovarian fluid is "blind passed" in a separate test for the North American strain of viral hemorrhagic septicemia. These pathogens do not occur in Idaho but have recently been identified in fish reared at a seawater net pen location in close proximity to the Manchester site. Results of fish health analyses on spawned fish are used by IDFG and the CSCPTOC to determine the disposition of eggs and subsequent juveniles.

Growth and Survival of Brood Year 1997

Program year 2002 represented the end of contribution from brood year 1997 individuals. In order to track the contribution of this cohort through time, growth, sources and magnitudes of mortality, and maturation rates were evaluated. Fish weights collected during routine sampling at both Eagle and Manchester were plotted over time, and both individual fish weight and group means are presented graphically. Major sources of mortality were compiled

including disease, tagging, mechanical (e.g., equipment failure), and maturation related sources. Mortality from Eagle and Manchester were combined into a single analysis. Finally, we determined the total number of brood year 1997 program fish from each study stream that reached sexual maturity and computed the percentage that matured at age-2, -3, -4, and -5.

Volitional Spawning

We prepared a 9.7 km section of the WFYF to receive maturing Chinook salmon from the captive rearing program to assess their spawning behavior and success in a natural environment. The components of a blocking weir are flown to the construction site via helicopter and assembled at the downstream end of this section to ensure that project fish remain in the study area above. Trap boxes built into the weir allow wild Chinook salmon and other native species to pass in either direction. The study section is then divided into six reaches approximately 1.6 km in length to permit systematic observations of Chinook salmon spawning above the weir. No project control is imposed on the upstream movement of study fish, but habitat changes above the confluence of the WFYF and Cabin Creek make spawning above this point unlikely (personnel observation). Finally, thermographs are deployed at the weir and near the upper extent of the study section to document the thermal histories of any redds spawned by captive-reared individuals and to determine when these redds should be sampled to determine fertilization rates and survival to the eyed-egg stage of development.

Following weir construction, maturing captive-reared Chinook salmon are transported by truck from Eagle to a helipad near the U.S. Forest Service Bonanza Guard Station (Challis National Forest) in preparation for release into the study section. The truck's hauling tank is divided into three compartments, into which fish from the two temperature treatments and the "late-arrivals" are segregated during transport. Water temperature in the transport tank is maintained at 11°C, which is approximately the stream temperature they are released into and also represents a compromise temperature appropriate for the transport of both study groups. At the helipad, fish are transferred to insulated coolers filled with water from the transport tank. The coolers are secured inside specially constructed steel frames (Figure 4A) for transport under the helicopter during the approximately 2 km flight to the release site. Transport frames are secured to the helicopter with a 30.5 m steel cable (Figure 4B).
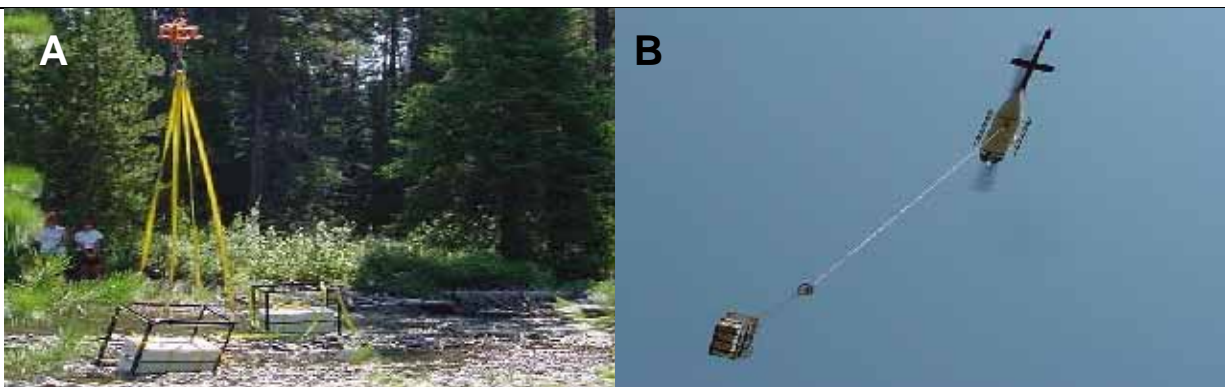
Figure 4.   Equipment used to fly mature adult Chinook salmon into the West Fork Yankee Fork Salmon River for volitional spawning. A) Steel-frame cages with coolers securely fastened inside. B) Helicopter with synthetic cable carrying an aluminum-frame cage.

Behavioral data collection begins approximately 24 h after fish are released. Observers are assigned three stream reaches to scan each day, which allows for monitoring the entire study section each day. Observers walk slowly upstream watching for Chinook salmon, and when one is detected the time is recorded and its habitat associations and activities (Table 1) are observed and documented for five minutes. During this time, the observer also uses binoculars and polarized sunglasses to determine if it is a wild or a study fish based on the presence or absence of a disc tag. If it is a study fish, the identification color combination and/or number of the tag is recorded. If the number can be determined (or the fish is wild), its location is recorded on a global positioning system (GPS) receiver. When multiple fish are observed simultaneously, their activity, habitat, and location information are recorded separately.

Table 1.   Habitat and behavior variables recorded during observations of captive-reared Chinook salmon released into the West Fork Yankee Fork Salmon River for volitional spawning, August–October 2002.

Habitat	Definition
Overhead vegetation	Associated with riparian vegetation overhanging the stream
Aquatic vegetation	Associated with aquatic vegetation
Cut bank	Under an overhanging bank
Pool	In a pool with no other structure
Riffle or run	In a riffle or run with no other structure
Riffle tail-out	In the tail-out section of a riffle with no other structure
Large woody debris	Within one body length of log(s)

General Behavior	Definition
Holding	Remaining in one position
Milling	Movement not resulting in displacement
Moving (A)	Movement in an upstream direction
Moving (B)	Movement in a downstream direction
Aggression	Aggression between Chinook of undetermined sex
Redd Holding	Maintaining position on or near a redd
Courting	Active male and receptive female
Spawn	Observed release of eggs and milt

Male Behavior	Definition
Quiver	Dart toward female ending with body vibrations
Crossover	Movement to opposite side, head passing over peduncle
Aggression (A)	Male on male aggression
Aggression (B)	Male on female aggression
Aggression (C)	Male on other species aggression
Following	Female present, no redd
Satellite	Holding away or downstream of a courting pair

Female Behavior	Definition
Aggression (A)	Female on female aggression
Aggression (B)	Female on male aggression
Aggression (C)	Female on other species aggression
Test dig	2–6 body flexures, not concentrated
Nest dig	5–8 body flexures in a concentrated area
Cover dig	8–12 body flexures along redd perimeter

When spawning related behaviors are observed during the first five minutes of observation, additional time is spent recording the frequency of these behaviors to estimate how close the pair is to spawning. If, based on these frequencies, the observers feel spawning would occur within 1-2 h, they remain with that pair and record their behaviors until 30 min after spawning. Behavioral observations are recorded in 10 minute-blocks during this time to facilitate comparisons of courting, aggression, and digging frequencies as spawning approaches.

Radio-telemetry is also used to collect additional information on the movements, distribution, and fate of marked individuals. This technique is used early in the season to estimate how far upstream study fish have traveled and allows us to concentrate observation efforts in areas known to contain fish. Telemetry is also used to locate individuals associated with logjams and other dense cover that would otherwise not be visible to shoreline observers. Finally, radio-telemetry is used to locate carcasses in an attempt to determine the cause of mortality and whether or not the fish spawned.

In addition to releasing fish into the WFYF, mature captive-reared Chinook salmon are also released into the EFSR. In contrast to the methods for release in the WFYF, fish in the EFSR are carried approximately 10–30 meters to the stream by hand, either in water filled, rubberized canvas sleeves or in insulated coolers from transport trucks described above. If fish move out of the reaches observers had permission to access, researchers continued to monitor fish movements via radio-telemetry to measure the frequency, magnitude, and direction of fish movement during the spawning season. Trackers zero the vehicle's odometer at the confluence of Herd Creek and the EFSR and drive the East Fork Salmon River Road, which runs parallel to the river, scanning the tag frequencies to locate fish. When a signal is detected, trackers drive ahead slowly until the maximum signal strength is obtained. The fish's location in the stream is assumed to be on a line from the vehicle perpendicular to the river. Mileage is recorded from the odometer of the vehicle, and a GPS location is taken. Straight-line estimates of movement for individual fish are calculated from the difference between successive GPS locations.

Production Estimation

Chinook salmon parr are collected while present in the WFYF to obtain fin clips for genetic analysis to determine if program parents produced them. Parr are collected using aquarium dip-nets throughout the study section, although particular emphasis is given to areas near known spawning locations. A similar method has proven to be safe and effective for capturing juvenile bull trout *Salvelinus confluentus* and juvenile cutthroat trout *O. clarki* (Bonneau et al. 1995). Once captured, the parr are transferred to tubs located on the shore filled with fresh stream water and lightly anesthetized with buffered MS-222. A small portion of the anal fin is removed and preserved in 95% ethanol. Scissors used to remove fin tissue are swabbed with isopropyl alcohol between specimens to reduce the possibility of DNA cross-contamination. The fish are also measured to the nearest 1 mm FL before being placed into a tub of fresh stream water to recover. Parr are then released back into the stream near their point of collection once sampling is completed at that site. Microsatellite markers will be utilized to conduct parentage analysis (parental exclusion analysis; Colbourne et al. 1996; Talbot et al. 1996; Estoup et al. 1998; Bernatchez and Duchesne 2000; Eldridge et al. 2002) to determine the relative reproductive success of captive-reared adults (adults released for volitional spawning in 2001) in terms of F_1 progeny (parr collected in 2002).

After the completion of spawning activities, eggs are collected from redds spawned by captive-reared females to determine the fertilization rate in these redds and to determine if this

measure of gamete quality is influenced by the temperature history of the female while at Eagle. Eggs are collected using the methods described above with the exception that sampling begins near the center of egg bearing structures to minimize sampling time, and most eggs have not received 300 CTUs. We believe this is justified due to the experimental nature of these redds. Opaque eggs or those having fungal growth are considered dead and are preserved in 95% ethanol. Clear eggs are classified as viable and are placed in Stockard's solution, which causes pre-eyed embryos to become visible. Eggs in this category are further categorized as fertilized or blank depending on the presence or absence of an embryo. The number of eggs in each category is enumerated and the percentage in each computed. Finally, the number of eyed-eggs produced by captive-reared females is estimated from the proportion of fertilized eggs observed, estimated fecundity, and the total number of redds produced by program females.

RESULTS AND DISCUSSION

Brood Year Report Outline

The following acronyms are used in the next section of the report to describe culture groups: NP refers to "natural parr" or fish collected from natal streams as wild parr; SN refers to "safety net" or fish generated from hatchery spawning events; and NE refers to "natural egg" or fish generated from the collection of eyed-eggs from redds constructed by wild adults.

Brood Year 1997

At the beginning of the reporting period, two WFYF-NP brood year 1997 Chinook salmon were in culture at Eagle. Ten (7 females/1 male/2 unknown) maturing LEM-NP and 33 (26 females/1 male/6 unknown) maturing WFYF-NP were transferred to Eagle from Manchester on April 23 and June 11, 2002 to complete their maturation in freshwater. On August 8, 2002, 27 maturing WFYF-NP were released into the WFYF for natural spawning and evaluation. Eight maturing LEM-NP (6 females/2 male) were used for hatchery spawning in 2002. At the end of the reporting period, zero WFYF-NP and zero LEM-NP fish remained in culture at Eagle (Tables 2, 4).

Brood Year 1998

At the beginning of the reporting period, three EFSR-SN, two EFSR-NP and two LEM-NP brood year 1998 Chinook salmon were in culture at Eagle. Fifty-six (43 females/6 males/7 unknown) maturing LEM-NP, 65 (36 females/21 males/8 unknown) maturing WFYF-NP, 30 (17 females/10 males/3 unknown) maturing EFSR-NP and 18 (15 females/3 males) maturing EFSR-SN were transferred to Eagle from the Manchester on April 23 and June 11, 2002 to complete their maturation in freshwater. On August 8, 2002, 56 maturing WFYF-NP were released into the WFYF for natural spawning and evaluation. On August 6 and 7, 2002, 17 EFSR-SN and 29 EFSR-NP were released into the EFSR for natural spawning and evaluation. Forty-eight maturing LEM-NP (41 females/7 males) were used for hatchery spawning in 2002. At the end of the reporting period, zero LEM-NP, zero WFYF-NP, zero EFSR-NP and zero EFSR-SN fish remained in culture at Eagle (Tables 2, 3, 4).

Brood Year 1999

At the beginning of the reporting period, 18 LEM-NE, 21 WFYF-SN, 15 EFSR-NE and 10 EFSR-SN were in culture at Eagle. Forty-one (0 females/41 males) maturing LEM-NE, 69 (0 females/69 males) maturing WFYF-SN, 25 (0 females/25 males) maturing EFSR-NE and 9 (1 female/8 males) maturing EFSR-SN were transferred to Eagle from the Manchester on April 23 and June 11, 2002 to complete their maturation in freshwater. On August 8, 2002, 76 maturing WFYF-NE were released into the WFYF for natural spawning and evaluation. On August 6 and 7, 2002, 13 EFSR-SN and 30 EFSR-NE were released into the EFSR for natural spawning and evaluation. Thirty-six maturing LEM-NP (0 females/36 males) were used for hatchery spawning in 2002. At the end of the reporting period, six LEM-NE, four WFYF-NE, zero EFSR-NE and one EFSR-SN fish remained in culture at Eagle (Tables 2, 3, 4).

Brood Year 2000

At the beginning of the reporting period, 283 WFYF-NE, 463 EFSR-NE and 220 YFSR-NE were in culture Eagle. On April 25, 2002, 10 EFSR-NE and 9 WFYF-NE smolts were transferred to Manchester to be used as sentinel groups for rearing in saltwater. On May 2, 2002, 369 EFSR-NE and 194 WFYF-NE smolts were transferred to Manchester to complete rearing in saltwater (Tables 2, 3, 5). On May 9, 2002, 219 YFSR-NE smolts were released into the Yankee Fork Salmon River for volitional spawning and evaluation. On August 8, 2002, 56 maturing WFYF-NE were released into the WFYF for natural spawning and evaluation. On August 7, 2002, 41 EFSR-NE were released into the EFSR for natural spawning and evaluation. Milt from ten WFYF-NE and ten EFSR-NE males were cryopreserved on September 30, 2002. At the end of this reporting period, zero WFYF-NE and zero EFSR-NE remained in culture at Eagle (Tables 2, 3).

Brood Year 2001

At the beginning of the reporting period, 265 WFYF-NE and 295 EFSR-NE were in culture at Eagle. At the end of the reporting period, 258 WFYF-NE and 284 EFSR-NE presmolts were on station at Eagle (Tables 2, 3).

Brood Year 2002

Eyed-egg collections in 2001 resulted in an initial inventory of 308 WFYF-NE and 328 EFSR-NE eyed-eggs. At the end of the reporting 284 WFYF-NE and 317 EFSR-NE developing fry were in culture.

Table 2. Summary of losses and magnitude of mortality for six West Fork Yankee Fork Salmon River captive Chinook salmon culture groups reared at the Eagle Fish Hatchery in 2002. Fish were from brood years (BY) 1997–2002 and were sourced as naturally spawned parr (NP), safety net hatchery crosses (SN), or naturally spawned eggs (NE).

	BY97-NP	BY98-NP	BY99-SN	BY00-NE	BY01-NE	BY02-NE
Starting Inventory (January 1, 2002)	2	0	21	283[a]	265[a]	308[b]
Eyed-Egg to Fry						
Undetermined[c]	n/a	n/a	n/a	n/a	n/a	24
Mechanical Loss						
Handling	0	1	6	0	0	0
Jump-out	0	1	0	0	5	0
Transportation	5	4	0	0	0	0
Noninfectious						
Lymphosarcoma	0	0	0	0	0	0
Nephroblastoma	0	0	0	0	0	0
Other[d]	3	3	4	14	2	0
Infectious						
Bacterial	0	0	0	0	0	0
Viral	0	0	0	0	0	0
Other	0	0	0	0	0	0
Hatchery Spawning						
Male Spawners	0	0	0	0	0	0
Female Spawners	0	0	0	0	0	0
Cryopreservation	0	0	0	10	0	0
Relocation						
Transferred In	33	65	69	0	0	0
Transferred Out	0	0	0	203	0	0
Planted/Released	27	56	76	56	0	0
Ending Inventory (December 31, 2002)	0	0	4	0	258	284

[a] Starting inventory reflects inventory adjustments made post-completion of the 2001 BPA Annual Report.
[b] Fall 2001 inventory.
[c] Typical egg to fry mortality includes non-hatching eggs, abnormal fry, and swim-up loss.
[d] Includes mortality due to maturation; culling associated with cultural anomalies; and all undetermined, noninfectious mortality.

Table 3. Summary of losses and magnitude of mortality for seven East Fork Salmon River captive Chinook salmon culture groups reared at IDFG facilities in 2002. Fish were from brood years (BY) 1998–2002 and were sourced as naturally spawned parr (NP), naturally spawned eggs (NE), or hatchery spawned safety nets (SN).

	BY98-SN	BY98-NP	BY99-SN	BY99-NE	BY00-NE	BY01-NE	BY02-NE
Starting Inventory (January 1, 2002)	3	2	10	15	463	295	328[a]
Eyed-Egg to Fry							
Undetermined[b]	n/a	n/a	n/a	n/a	n/a	n/a	11
Mechanical Loss							
Handling	2	1	3	7	6	0	0
Jump-out	0	0	0	0	0	9	0
Transportation	0	0	0	0	0	0	0
Noninfectious							
Lymphosarcoma	0	0	0	0	0	0	0
Nephroblastoma	0	0	0	0	0	0	0
Other[c]	2	2	2	3	27	2	0
Infectious							
Bacterial	0	0	0	0	0	0	0
Viral	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
Hatchery Spawning							
Male Spawners	0	0	0	0	0	0	0
Female Spawners	0	0	0	0	0	0	0
Cryopreservation	0	0	0	0	10	0	0
Relocation							
Transferred In	18	30	9	25	0	0	0
Transferred Out	0	0	0	0	379	0	0
Planted/Released	17	29	13	30	41	0	0
Ending Inventory (December 31, 2002)	0	0	1	0	0	284	317

[a] Fall 2001 inventory.
[b] Typical egg to fry mortality includes non-hatching eggs, abnormal fry, and swim-up loss.
[c] Includes mortality due to maturation; culling associated with cultural anomalies; and all undetermined, noninfectious mortality.

Table 4. Summary of losses and magnitude of mortality for four Lemhi River captive Chinook salmon culture groups reared at IDFG facilities in 2002. Fish were from brood years (BY) 1997–1999 and were sourced as either naturally spawned parr (NP) or naturally spawned eggs (NE).

	BY97-NP	BY98-NP	BY99-NE
Starting Inventory (January 1, 2002)	0	2	18
Eyed-Egg to Fry			
Undetermined[a]	n/a	n/a	n/a
Mechanical Loss			
Handling	0	1	8
Jump-out	0	1	0
Transportation	0	1	0
Noninfectious			
Lymphosarcoma	0	0	1
Nephroblastoma	0	0	0
Other[b]	2	6	8
Infectious			
Bacterial	0	0	0
Viral	0	0	0
Other	0	0	0
Hatchery Spawning			
Male Spawners	2	7	36
Female Spawners	6	41	0
Cryopreservation	0	0	0
Relocation			
Transferred In	10	55	41
Transferred Out	0	0	0
Planted/Released	0	0	0
Ending Inventory (December 31, 2002)	0	0	6

[a] Typical egg to fry mortality includes non-hatching eggs, abnormal fry, and swim-up loss.
[b] Includes mortality due to maturation; culling associated with cultural anomalies; and all undetermined, noninfectious mortality.

Table 5.   Summary of losses and magnitude of mortality for one Yankee Fork Salmon River captive Chinook salmon culture groups reared at IDFG facilities in 2002. Fish were from brood year (BY) 2000 and sourced as naturally spawned eggs (NE).

	BY00-NE
Starting Inventory (January 1, 2002)	220
Eyed-Egg to Fry	
Undetermined[a]	n/a
Mechanical Loss	
Handling	0
Jump-out	0
Transportation	1
Noninfectious	
Lymphosarcoma	0
Nephroblastoma	0
Other[b]	0
Infectious	
Bacterial	0
Viral	0
Other	0
Hatchery Spawning	
Male Spawners	0
Female Spawners	0
Cryopreservation	0
Relocation	
Transferred In	0
Transferred Out	0
Planted/Released	219
Ending Inventory (December 31, 2002)	0

[a] Typical egg to fry mortality includes non-hatching eggs, abnormal fry, and swim-up loss.
[b] Includes mortality due to maturation; culling associated with cultural anomalies; and all undetermined, noninfectious mortality.

Eyed Egg Collection, Transport, and Incubation

Naturally spawned, eyed-eggs were collected from the EFSR and the WFYF to establish captive culture groups representing brood year 2002. Eyed-eggs were collected from four redds in the EFSR on September 24, 2002 and from three redds on the WFYF on September 20 and an additional two redds on October 7, 2002. Collections totaled 328 eyed-eggs from the EFSR

and 308 from the WFYF (Table 6). The eyed-eggs were transported to Eagle as soon as possible after collection and were in incubators within 4–6 h of removal from the redds. Percent survival to ponding was 96.7% for the EFSR eggs and 92.2% for the WFYF eggs. Estimated CTUs to hatch ranged from 439.8 to 650.2 for the EFSR eggs and 437.8 to 557.8 for the WFYF eggs.

Table 6. Summary of number of eyed-egg collected and estimated CTUs at collection in the East Fork Salmon River (EFSR) and the West Fork Yankee Fork Salmon River (WFYF) to establish brood year 2002 culture groups at the Eagle Fish Hatchery.

Date	Stream	Redd 1	CTUs	Redd 2	CTUs	Redd 3	CTUs	Redd 4	CTUs	Redd 5	CTUs	Egg total
9/24/02	EFSR	121	374	97	331	52	385	58	374	—		328
Total	EFSR											328
9/20/02	WFYF	64	380	77	347	63		—		—		204
10/07/02	WFYF	—		—		—		51	321	53	321	104
Total	WFYF											308

Eyed-eggs were produced at Eagle when maturing LEM program fish were spawned to assess the effect of water temperature on gamete quality and maturation timing. A total of 47 females (46 Manchester and 1 Eagle reared) and 42 males (40 Manchester and 2 Eagle reared) were used in these crosses (Appendix A). Eggs were incubated by subfamily at approximately 13.7°C. Incubators were checked daily and dead eggs were removed and enumerated from each incubator. At approximately 270 CTUs, the eggs had developed a soft eye and were shocked. When eggs had accumulated approximately 372 CTUs, they were transferred to in-stream incubators operated by personnel from the Shoshone-Bannock Tribe.

Juvenile Rearing, Marking, and Transportation

In April 2002, brood year 2000 juveniles from the WFYF and EFSR were handled twice in preparation for transfer to Manchester. On April 9, 2002, brood year 2000 juveniles from these stocks were marked with an elastomer tag and vaccinated against BKD and vibrio. Then on April 24–25, 2002, these fish were weighed and measured, and an Aloka SSD-500V ultrasound unit with an Aloka Electronic Linear Probe UST-556L-7.5 was used to identify precocially maturing males from these groups. Fish determined to be precocial remained at Eagle and were released to spawn volitionally. Smolts from the WFYF (N = 280) averaged 248.1 mm FL (range 114–320 mm) and 159.1 g (range 38–348 g). Smolts from the EFSR (N = 446) averaged 241.5 mm FL (range 174–325 mm) and 142.4 g (range 48.5–312 mm). These smolts were larger than previous cohorts. The larger size could be explained by their being reared on ambient temperature water for a longer period of time at Eagle while a new well field was constructed and brought on line.

Brood year 2000 juvenile Chinook salmon were transferred from Eagle to Manchester as smolts on two occasions in 2002. The first transfer took place on April 25 and included 10 fish from the EFSR-NE group and nine fish from the WFYF-NE group. These fish acted as sentinels to test each group's ability to tolerate saltwater. No adverse effects were observed during their acclimation, and an additional 369 EFSR-NE smolts and 194 WFYF-NE smolts were transferred on May 2, 2002 (Appendix B).

The brood year 2000 smolts from the YFSR were transported to the river and released near their point of collection. A total of 219 fish, with a mean weight of 97 g, were released near the confluence of the YFSR and Rankin Creek on April 2, 2002. None of these fish have been detected at downstream PIT-tag interrogation sites to date.

Two culture groups of juvenile Chinook salmon representing brood year 2001, totaling 551 fish, were PIT tagged on July 2, 2002 (Table 7). A total of 291 EFSR fish and 260 WFYF fish were PIT tagged during the process. The length and weight of brood year 2001 juveniles were smaller than in previous years (Venditti et. al. 2003), which can be attributed to rearing in chilled water and improved diet regime. Fish from the WFYF averaged 90.8 mm FL and 8.2 g while EFSR fish averaged 84.8 mm FL and 6.9 g.

Table 7.   Source stream, culture group type, and number of brood year 2001 juvenile Chinook salmon PIT tagged in the IDFG captive rearing project during 2002. Source streams include the West Fork Yankee Fork Salmon River (WFYF) and East Fork Salmon River (EFSR). All culture groups were collected as eyed-eggs and are referred to as natural egg collections (NE).

Source Stream	Tag Date	Number
EFSR-NE	7/02/02	291
WFYF-NE	7/02/02	260

Adult Rearing, Marking, and Transportation

Adult Chinook salmon from the WFYF, EFSR, and LEM stocks determined to be maturing at Manchester were transferred to Eagle on two separate occasions in 2002. The first transport occurred on April 23 and included fish from brood years 1997, 1998, and 1999. Two hundred ninety-five fish were shipped during the first transport. Adults determined to be maturing during a second sort were transferred on June 11 and contained 43 individuals from brood year 1998 and 18 from brood year 1999 (Appendix B).

Maturing fish from the EFSR and WFYF were disc and radio tagged at Eagle between July 22-24 in preparation for release into their natal streams (Appendix C). A total of 350 fish were tagged during the three days. Fifty brood year 1998 adults averaging 1,955 g (range 487–3,572 g), 43 brood year 1999 adults averaging 959 g (range 155–1,879 g), and 41 brood year 2000 adults averaging 134 g (range 68–200 g) were tagged from the EFSR. Twenty-seven brood year 1997 adults averaging 2,338 g (range 1,295–4,071 g), 56 adults from 1998 averaging 2987 g (N = 53, range 1,399–4,813 g), 77 brood year 1999 adults averaging 898 g (range 444–2,413 g), and 56 brood year 2000 adults averaging 170 g (N = 54, range 53–300 g) were tagged from the WFYF stock. A small number of fish from each stock (12 WFYF and 23 EFSR) also received gastrically implanted radio transmitter at that time (Appendix C). Radio-tagged fish from brood years 1997, 1998, and 1999 averaged 3,067 g (N = 3), 3,353 g (N = 8), and 1,024 g (N = 1), respectively, from the WFYF, while radio-tagged fish from the EFSR averaged 2,314 g (N = 14) for brood year 1998 and 1,188 g (N = 9) for brood year 1999. Individual weights of brood year 1997 and 1998 WFYF fish that were radio tagged were not

significantly different from those that received only disc tags (two-sample t-test; 1997 P = 0.276 and 1998 P = 0.474; SYSTAT 2000). Statistical comparisons were not made to compare the size of radio-tagged brood year 1999 fish since only one individual from that brood year was radio tagged. The average weights of radio-tagged fish from the EFSR were found to be significantly heavier than those only receiving disc tags (two-sample t-test; 1998 P = 0.024 and 1999 P = 0.001; SYSTAT 2000).

Chilled Water Experiment

Experimental groups of fish exposed to the two temperature treatments experienced an average difference of 4.7°C during their freshwater maturation period at Eagle. Water temperature in the test tanks averaged 8.9°C (range 8.0°C–13.6°C, SD = 0.80), while water temperature in control tanks averaged 13.8°C (13.4°C–14.3°C, SD = 0.17) without shade cover and 13.6°C (13.4°C–14.0°C, SD = 0.09) in the shade covered control tanks (Figure 5). Temperature differences between the shaded ambient tank and the chilled tank were significant (two sample t-test; P < 0.001; SYSTAT 2000). A statistically significant difference was also observed between the shaded and unshaded ambient temperature tanks (two sample t-test; P <0.001; SYSTAT 2000), although the 0.2°C difference likely had little or no biological significance.

Mean fish weight in the chilled and ambient temperature groups for all brood years did not differ significantly (two sample t-test, P >0.05, SYSTAT 2000), while those groups classified as 'large' had mean weights that were significantly greater than those groups classified as 'small' for their respective brood years (two sample t-Test, P <0.05, SYSTAT 2000) in all cases (Table 8). Further analysis of treatment classifications showed no significant differences between experimental groups, whereas mean weight differences between 'small' and 'large' group fish, in various pairings, were always significant (Table 8).
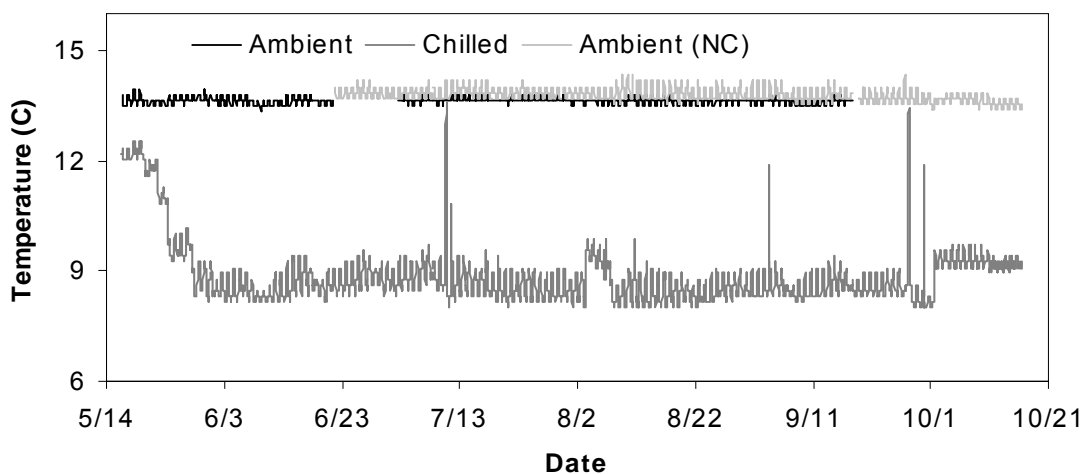
Figure 5. Chilled, covered ambient tank, and uncovered ambient tank (NC) water temperatures experienced by maturing captive-reared Chinook salmon at the Eagle Fish Hatchery during their final freshwater maturation, May–October 2002.

Table 8.　Statistical comparisons of overall mean fish weights of Lemhi River (LEM) and West Fork Yankee Fork (WFYF) Chinook salmon from brood years (BY) 1997, 1998, and 1999 used in the temperature manipulation experiment to advance maturation timing. Fish were randomly assigned to either chilled (T) or ambient (C) water, and designated either large (L) or small (S) depending on size relative to the overall group mean weight. Block one examines similarities of weight in temperature groups within brood years. Block two examines differences of weight in size classes within brood years. Block three examines similarities of weight in treatment groups within brood year and size classes. Block four examines differences of weight in size classes within treatment groups and brood years. Blocks are separated in the table by a solid horizontal line.

Stock	BY	Group	Size	N	Mean	SD	P-Value
WFYF	1997	C		13	2295.9	702.188	0.445
		T		14	2520.3	794.116	
WFYF	1998	C		25	3041.4	886.886	0.618
		T		22	3174.3	926.018	
WFYF	1999	C		33	798.7	129.851	0.604
		T		35	781.7	138.238	
LEM	1997	C		5	2072.6	453.289	0.949
		T		5	2103.0	931.902	
LEM	1998	C		16	2208.6	740.389	0.876
		T		18	2251.7	842.768	
LEM	1999	C		17	846.5	331.626	0.950
		T		18	840.9	170.661	
WFYF	1997		L	12	3110.1	483.164	0.000
			S	15	1854.0	312.59	
WFYF	1998		L	26	3778.5	436.808	0.000
			S	21	2268.0	539.344	
WFYF	1999		L	31	906.6	81.203	0.000
			S	37	692.2	78.394	
LEM	1997		L	4	2785.3	337.295	0.001
			S	6	1622.8	377.822	
LEM	1998		L	12	3050.6	712.161	0.000
			S	22	1784.6	330.152	
LEM	1997		L	17	1044.9	198.408	0.000
			S	18	653.5	129.689	
WFYF	1997	C	S	8	1875.3	284.418	0.790
		T	S	7	1829.7	363.771	
WFYF	1997	C	L	5	2969.0	646.079	0.419
		T	L	7	3210.9	348.244	
WFYF	1998	C	S	12	2260.4	474.174	0.943
		T	S	9	2278.1	646.431	
WFYF	1998	C	L	13	3762.2	440.68	0.854
		T	L	13	3794.7	450.258	
WFYF	1999	C	S	18	704.3	60.087	0.370
		T	S	19	680.8	92.726	
WFYF	1999	C	L	15	911.9	94.632	0.729
		T	L	16	901.6	69.095	
LEM	1997	C	S	3	1779.0	255.906	0.367
		T	S	3	1466.7	467.143	
LEM	1997	C	L	2	2513.0	210.718	0.068
		T	L	2	3057.5	20.506	

Table 8. Continued.

Stock	BY	Group	Size	N	Mean	SD	P-Value
LEM	1998	C	S	10	1765.1	306.06	0.807
		T	S	12	1800.8	361.686	
LEM	1998	C	L	6	2947.8	653.277	0.640
		T	L	6	3153.3	814.661	
LEM	1999	C	S	9	601.6	134.006	0.089
		T	S	9	705.4	108.223	
LEM	1999	C	L	8	1122.0	258.781	0.135
		T	L	9	976.3	94.349	
WFYF	1997	C	L	5	2969.0	646.079	0.001
		C	S	8	1875.3	284.418	
WFYF	1997	T	L	7	3210.9	348.244	0.000
		T	S	7	1829.7	363.771	
WFYF	1998	C	L	13	3762.2	440.68	0.000
		C	S	12	2260.4	474.174	
WFYF	1998	T	L	13	3794.7	450.258	0.000
		T	S	9	2278.1	646.431	
WFYF	1999	C	L	15	911.9	94.632	0.000
		C	S	18	704.3	60.087	
WFYF	1999	T	L	16	901.6	69.095	0.000
		T	S	19	680.8	92.726	
LEM	1997	C	L	2	2513.0	210.718	0.045
		C	S	3	1779.0	255.906	
LEM	1997	T	L	2	3057.5	20.506	0.020
		T	S	3	1466.7	467.143	
LEM	1998	C	L	6	2947.8	653.277	0.000
		C	S	10	1765.1	306.06	
LEM	1998	T	L	6	3153.3	814.661	0.000
		T	S	12	1800.8	361.686	
LEM	1999	C	L	8	1122.0	258.781	0.000
		C	S	9	601.6	134.006	
LEM	1999	T	L	9	976.3	94.349	0.000
		T	S	9	705.4	108.223	

Exposure to chilled water at Eagle produced mixed results in advancing maturation in program fish, but it did significantly increase the probability that a female would spawn under natural conditions. Lemhi River hatchery females matured and were spawned between September 16 and October 11, 2002 (Appendix A). In the first half of this period, 19 females were spawned including 10 test and 9 control individuals. Sixteen females matured during the second half of the spawning period including nine test and seven control fish. Additionally, 12 females were also spawned during the entirety of this spawning period but were not included in the temperature study because they were either late arrivals or were Eagle reared fish. These results indicate no detectable difference in the distribution of spawn timing in the two groups of females (Chi-square, P = 0.830, SYSTAT 2000). However, males from the chilled water treatment began running milt approximately two weeks earlier than males held on ambient temperature water. Females released into the WFYF spawned between August 19 and September 20, 2002. The first redds initiated by females from both experimental groups occurred within five days, and six control and seven treatment females spawned in the first half of the spawning period. No control and eight treatment females spawned in the second half of the period, which suggests the spawning distribution of control females was significantly earlier than for test females (Chi-square, P = 0.023, SYSTAT 2000). However, the interpretation of this result may be clouded by several factors. First, despite the fact that an equal number of females

from both groups were released, the number of test females that spawned (N = 15) was significantly larger than the number of control females that spawned (N = 6; Chi-square, P = 0.012, SYSTAT 2000). Second, based on these numbers, exposure to chilled water may have actually benefited program fish by either providing a survival advantage or an increased propensity to spawn. And finally, essentially the same number of females from both groups spawned during the first half of the spawning period, which suggests that temperature history may have had little influence on when the two groups of captive-reared females matured.

Hatchery Spawning and Gamete Evaluation

Maturing program fish from the LEM stock were spawned at Eagle to assess the effect of water temperature on gamete quality and maturation timing. A total of 47 females (46 Manchester and 1 Eagle reared) and 42 males (40 Manchester and 2 Eagle reared) were used in these crosses (Appendix A). Eggs from each female were divided into sublots and fertilized with milt from individual males as described above. Survival to the eyed stage was variable (0.0%—98.5%) and averaged 66.5% (Appendix A), but there were no statistically significant differences in survival between the treatment groups (ANOVA P = 0.104, SYSTAT 2000). When the eggs had reached the eyed stage of development, they were transferred from Eagle to in-stream incubators in the LEM drainage (Appendix B). The eggs were provided to cooperators with the Shoshone-Bannock Tribe on October 16, 23, and 31, 2002 and placed in in-stream incubators in Hayden Creek upstream of Bear Valley Creek. Tribal cooperators received 10,148 eyed-eggs on the first date, 18,319 on the second, and 19,510 eggs on the third. After distributing the eggs, Tribal biologists monitored the incubators to evaluate the hatch and emergence rates and dates.

Survival to the eyed-egg stage of growth appears to be a result of maternal rather than paternal contribution. Subfamilies from individual females survived at similar levels regardless of paternal contributors (Figure 6). In contrast, survival in subfamilies sired by individual males varied widely and was dependant on maternal influence (Figure 7). A similar trend was observed in hatchery crosses performed at Eagle during 2001 (Venditti et al. 2003).

Fish Health Monitoring

Monitoring for BKD in captive-reared Chinook salmon has been routinely conducted since the inception of the program in 1995. None of the 204 fish examined in 2002 demonstrated clinical levels of this disease using the enzyme-linked immunosorbent assay. This was the first year of not detecting BKD in Chinook broodstocks and reflects the transition to originating brood groups by safety-net or eyed-eggs in lieu of natural parr. Erythromycin-medicated feed for a 28-day duration was administered twice as a prophylactic treatment.

In 2002, Lemhi River Chinook salmon juveniles were not found to be infested with the gill parasite *Salmincola,* indicating that the gastric intubation treatment with the parasiticide Ivermectin and the shift from juvenile to eyed-egg collections was successful. In years prior to 2000, this infestation debilitated rearing groups of Lemhi River Chinook salmon.

Naturally produced juvenile Chinook salmon collected from the Lemhi River (and to a lesser extent, the West Fork Yankee Fork Salmon River) are infected with *Myxobolus cerebralis*, the causative agent of salmonid whirling disease. For captive broodstocks of Lemhi River Chinook salmon, the prevalence of infection for 2002 was 13%, which is lower than previously

observed and also reflects the benefits of originating broodstocks from eyed-eggs. Mortality has not been attributed to the parasite, but occasional deformities have been observed.

Motile aeromonad septicemia, caused by *Aeromonas* and *Pseudomonas spp.*, was detected in four broodstock groups (LEM 99, WFYF 99, EFSR 98, and EFSR 99) and required antibiotic therapy, which was effective in reducing loss.

There was considerable mortality in the EFSR-NE brood year 2000 Chinook that was due to fungus (*Saprolegnia* spp.). This condition did not respond to therapy.

There was a single case of a testicular tumor from the LEM 99-NE group. Tumors, primarily lymphosarcomas, have been detected in sockeye salmon captive broodstocks reared at Eagle. This was the first occurrence of a testicular tumor in program Chinook salmon and may indicate a water chemistry related induction, which has also been suspected with tumors of sockeye salmon. The tumor developed after three years of rearing at Eagle and is similar in timing to those that occur in the sockeye salmon broodstocks.

Growth and Survival of Brood Year 1997

Growth rate comparisons of brood year 1997 captive-reared Chinook salmon indicated that those from Manchester attained a larger size than those reared at Eagle. Sample weights collected from fish at Eagle in December 1998, March 1999, April 2000, and February 2001 show that program fish averaged 12.2 g, 29.0 g, 550.1 g, and 1,221.2 g, respectively (Figure 8). Only one brood year 1997 fish remained in culture at Eagle at age-5, which weighed 3,272 g. Sample weights collected at Manchester at approximately the same times indicated that fish there were almost twice as large as those at Eagle. Average weights of program fish at Manchester were 82.3 g, 710.4 g, 2455.1 g, and 2,246.3 g in July 1999, May 2000, May 2001, and April 2002, respectively (Figure 9). Chinook salmon reared at Manchester once again exhibited very little growth during their fifth year of life, which is consistent with previous observations (Venditti et al. 2002, 2003) and were generally smaller than many of those measured at age-4 (Figure 9).

General sources of mortality in this brood year were similar to those observed previously (Hassemer et al 2001, Venditti et al. 2002, 2003), although losses to BKD were much lower than in previous cohorts. Primary sources of mortality in this group included maturation, handling, and unexplained tank deaths (Figure 10). A small portion of maturing fish (2.8%) were sacrificed in an experiment performed in conjunction with scientists from NOAA Fisheries to monitor changes over time in physiological parameters associated with maturation in captive- and ocean-reared Chinook salmon. Results of this work are reported in Swanson et al. (2002).
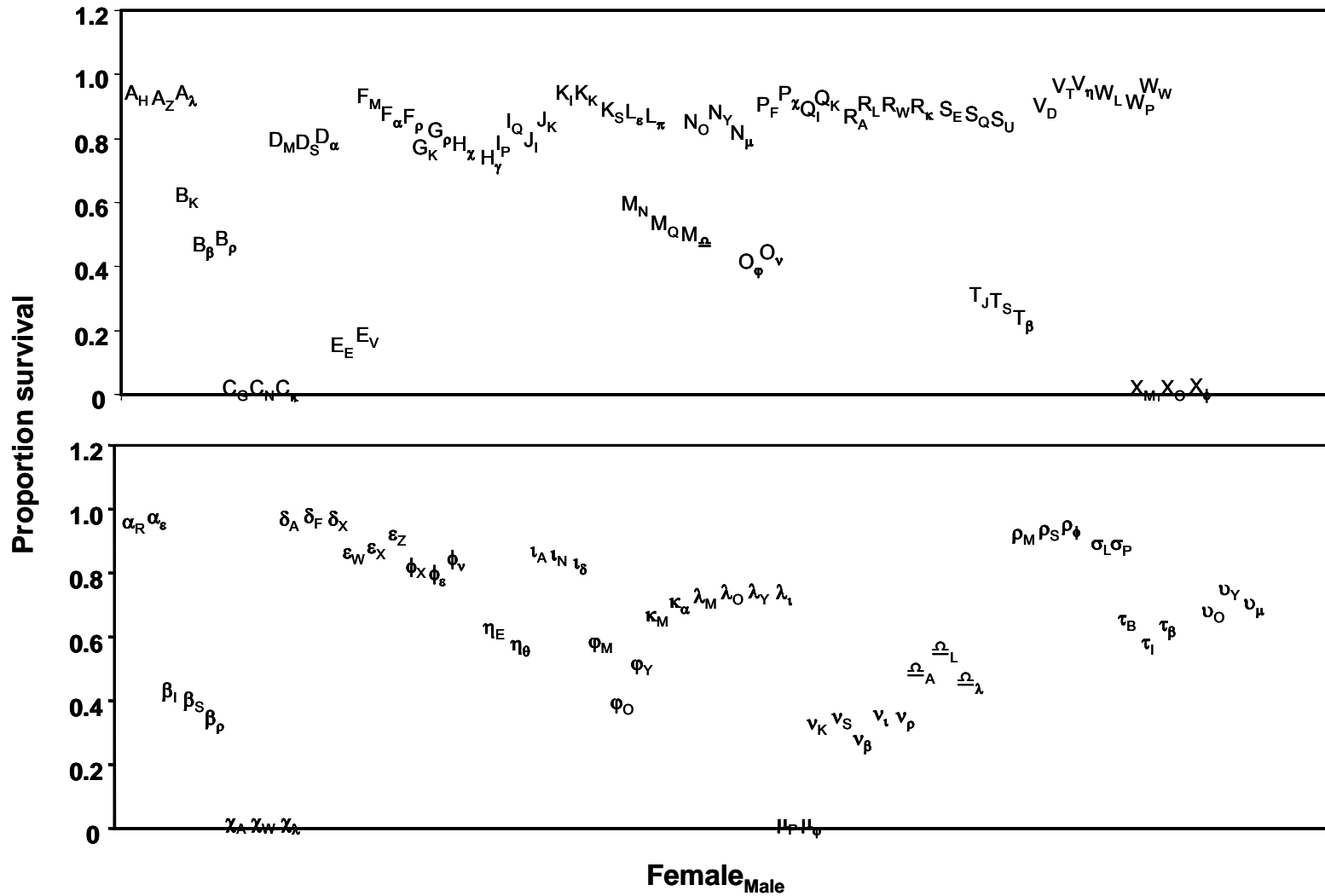
Figure 6. Proportion of green eggs harvested from individual females spawned at the Eagle Fish Hatchery that survived to the eyed stage of development. Green eggs were separated into multiple subfamilies of approximately equal size (identified by unique letters or symbols) whenever possible and fertilized with milt from program males (identified by unique subscripts). Females producing only one subfamily have been omitted.

Figure 7. Proportion of eggs fertilized by individual males (identified by unique letters or symbols) spawned at the Eagle Fish Hatchery that survived to the eyed stage of development. Egg lots (subfamilies) produced by individual females are identified by unique subscripts. Males used to fertilize only a single subfamily have been omitted.
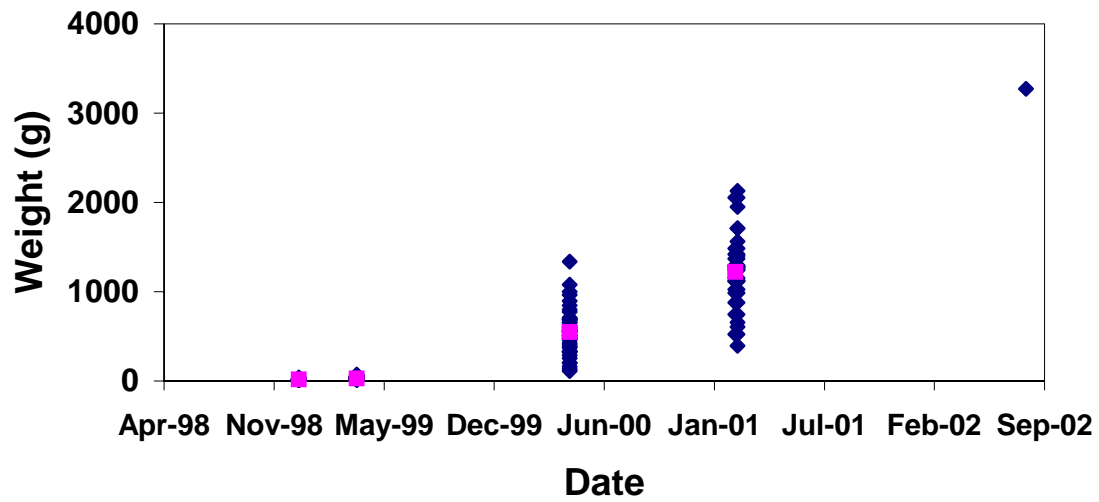
Figure 8.   Growth data for brood year 1997 fish reared in freshwater at the Eagle Fish Hatchery during their duration in the captive rearing program.
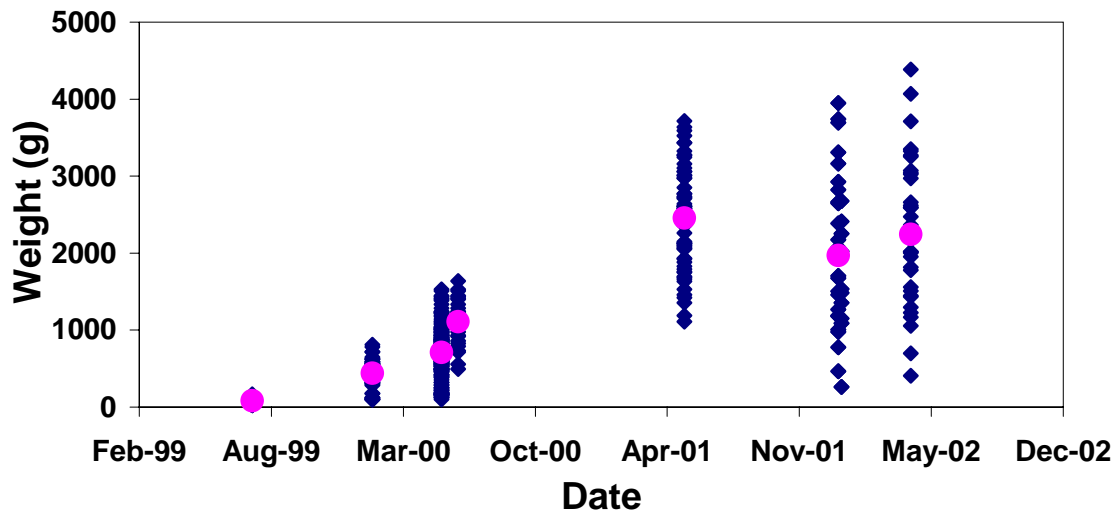
Figure 9.   Growth data for brood year 1997 fish reared in saltwater at the Manchester Marine Experimental Station during their duration in the captive rearing program.
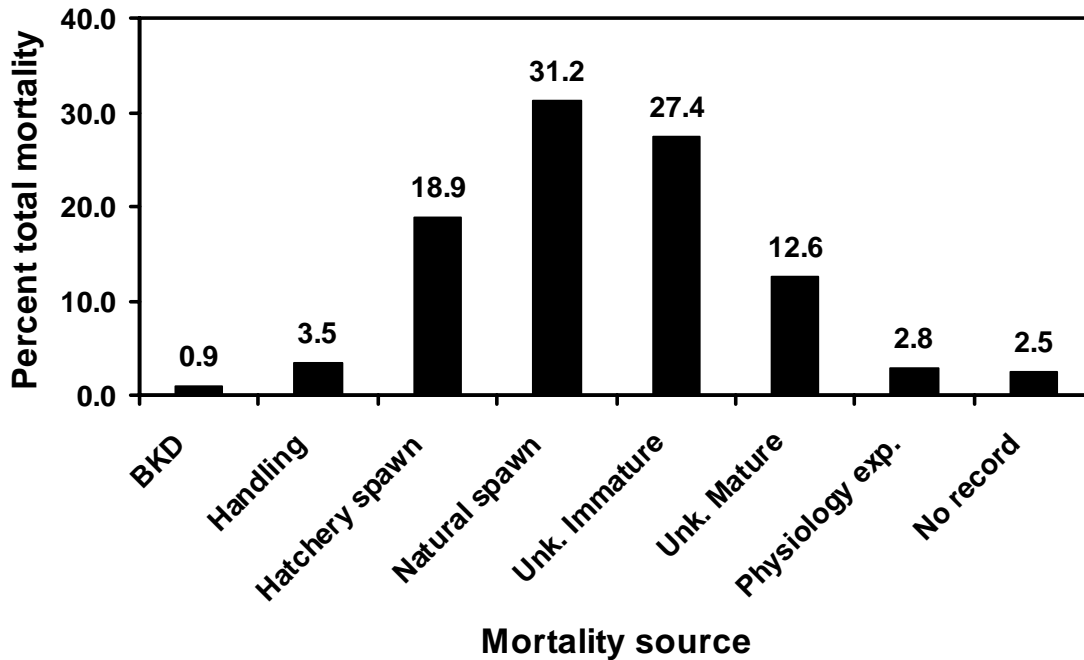
Figure 10   Primary sources of mortality in brood year 1997 captive-reared Chinook salmon during rearing at the Eagle Fish Hatchery and Manchester Marine Experimental Station. Abbreviations include Unk = Unknown, Physiology Exp. = physiology experiment.

Brood year 1997 captive-reared Chinook salmon matured at a higher overall rate than previous cohorts. Overall, 126 of 197 fish (66.0%) from the WFYF brought into the program matured, and of these, 19 males (15.7%) matured at age-2, 22 males (18.2%) matured at age-3, 41 females (33.9%) and seven males (5.8%) matured at age-4, and 29 females (24.0%) and three males (2.5%) matured at age-5. Precocity was higher than observed in earlier cohorts from the WFYF (Hassemer et al. 2001, Venditti et al. 2002), but similar to results observed in brood year 1996 (Venditti et al. 2003). In the LEM stock, 94 of 128 (73.4%) brood year 1997 program fish matured. Precocial maturation in this group was 12.8% (12 fish), while 19 (20.2%) males and two females (2.1%) matured at age-3, two males (2.1%) and 49 females (52.1%) matured at age-4, and four males (4.3%) and six females (6.4%) matured at age-5. Although a greater percentage of fish from this group matured than in previous years, the male contribution at age-4 and -5 remained limited.

Volitional Spawning

After being disc tagged, 215 WFYF fish and 130 EFSR fish were released back into their natal streams for volitional spawning. One WFYF and four EFSR fish died after being disc tagged but prior to release. Adult Chinook salmon were flown into the WFYF and released on August 8, 2002 (Appendix B). Releases into the EFSR occurred on August 6, 2002 (55 fish) and August 7, 2002 (75 fish; Appendix B). Release sites on both streams were widely spaced in order to reduce the density of fish at any one particular location.

Behavior and habitat associations of captive-reared Chinook salmon observed in the WFYF changed over time in a manner that reflected their changing requirements as they neared spawning. Initially, study fish were generally observed to be associated with pools, large woody debris, or runs (Figure 11), and were most often observed holding position or moving (Figure 12). Such behavior and habitat associations are in accord with prespawn Atlantic salmon reported by Bardonnet and Baglinière (2000). This behavioral adaptation of selecting habitats with low water velocity and complex structures may benefit them by helping to conserve depleted energy reserves for future spawning activities (Torgersen et al. 1999) or by providing refuge from predators. As this study progressed, spawning related behaviors including courting and maintaining or holding on redds became the dominant activities observed (Figure 11). During this time, fish were mainly associated with pool tail-outs, although pools and large woody debris remained important as resting and staging areas (Figure 12), which also follows the observations of spawning Atlantic salmon by Bardonnet and Baglinière (2000).

Twenty-six captive-reared females (10 brood year 1997, 15 brood year 1998, and one unknown brood year fish that had lost its tag) constructed 33 redds in the WFYF during 2002 (Table 9). The first redd initiated in 2002 was on August 19 by a brood year 1998 "late arrival." Redd construction peaked during the week of September 1–8, 2002 with 18 redds (54.5%) initiated during that period. The final redd was initiated on September 20 by a brood year 1998 treatment fish.

Behavioral observations from eight spawning events in which captive-reared Chinook salmon participated were observed in the WFYF during 2002. In seven of these, both fish were captive-reared and the eighth involved a captive-reared female and a wild male. Because a wild male was observed in only one pairing, behavioral comparisons between wild- and captive-reared males are made using last year's wild spawning observations and literature values. Crossover and quiver frequencies in captive-reared males remained constant or increased slightly as spawning neared (Figure 13) and followed a pattern similar to both Chinook and coho salmon spawning in experimental channels (Berejikian et. al 1997, 2001a, b). Courting rates were similar to those observed in program fish in 2001 (Venditti et al. 2003) and other hatchery origin Chinook salmon spawning in experimental channels (Berejikian et. al 2001b). Aggression levels in captive-reared and wild males were similar in 2002 (Figure 13) and only slightly less than the wild male average documented in 2001 (Venditti et al. 2003). This level of aggression appears rare in the literature. Other authors documenting aggression in captive- and wild-reared fish have found wild fish to be significantly more aggressive than their hatchery-bred counterparts (Fleming et al. 1996; Chebanov and Riddell 1998). The high levels of aggression observed in 2002 may be partially explained by the presence of only a few wild fish, resulting in the captive-reared males having less of a size disadvantage than would have otherwise been the case.

Captive-reared females displayed digging patterns similar to those reported in the literature. Study females made nest digs approximately every 2-3 minutes until egg deposition, then females proceeded to cover dig almost continuously for about 10 minutes and maintained elevated digging frequencies for at least 30 minutes (Figure 14). This general behavior pattern has been reported in Chinook salmon and coho salmon (Berejikian et al. 2001a, b) and coho salmon (Berejikian et al. 2001) and is probably common to stream spawning salmonids.

8/9 – 8/18

3.5%
27.4%
14.9%
31.5%
22.6%

8/19 – 9/1

1.6%
18.1%
8.9%
15.0%
25.2%
31.3%

9/2 – 9/15

2.5%
12.4%
10.7%
39.2%
35.2%

9/16 – 9/23

3.8%
5.7%
54.7%
35.8%

Vegetation   Cut Bank   Pool

Riffle/Run   Tailout   LWD
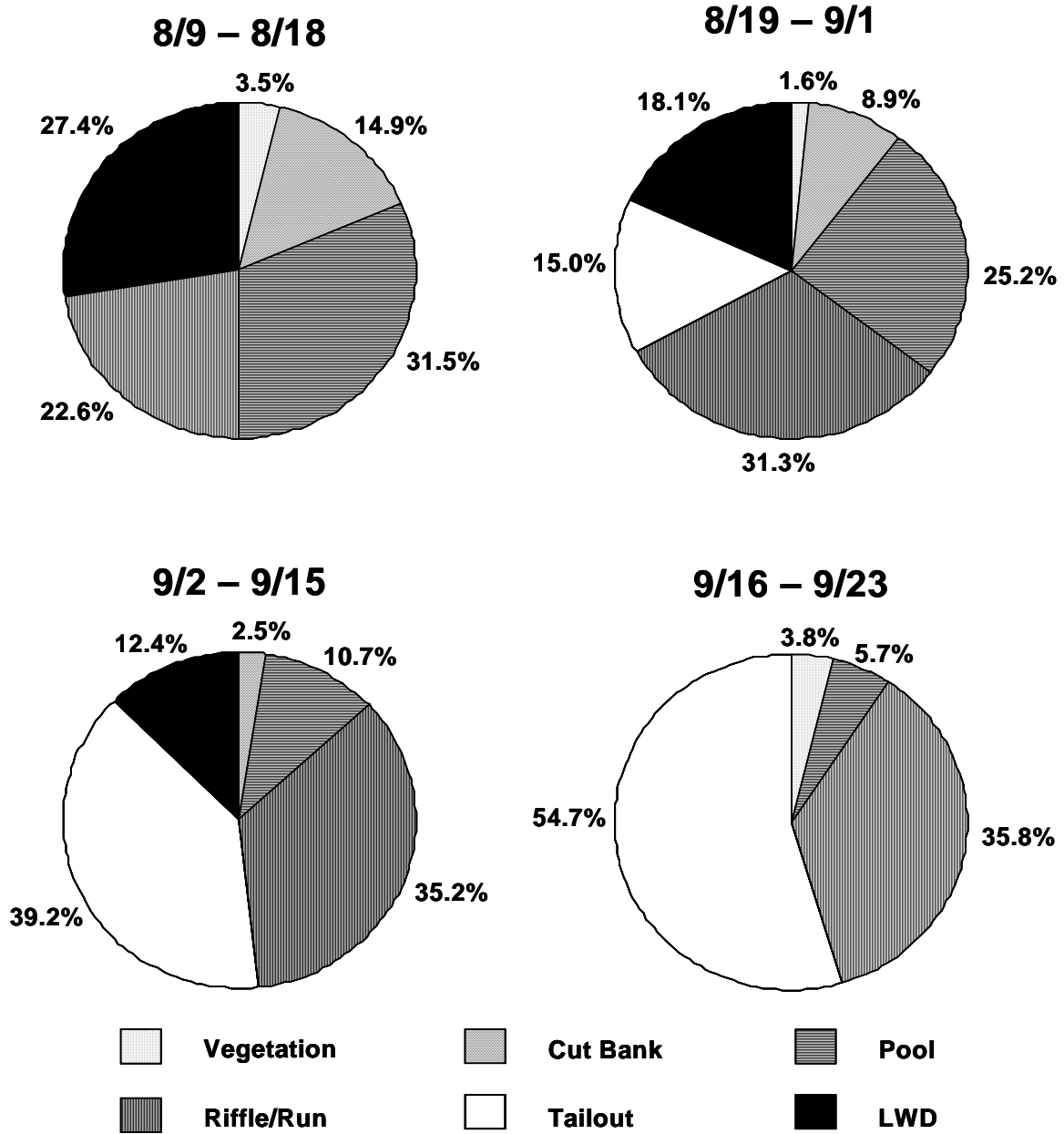
Figure 11. Habitat associations of captive-reared Chinook salmon released into the West Fork Yankee Fork Salmon River in the summer of 2002. Data were collected during standardized observation intervals of 5 min.

8/9 – 8/18

94.8%

1.1%

3.8%

8/19 – 9/1

3.0%

76.3%

8.3%

9.1%

3.2%

9/2 – 9/15

1.0%

40.3%

4.1%

35.3%

12.5%

7.0%

9/16 – 9/23

14.3%

11.9%

16.7%

2.4%

7.1%

47.6%

Holding   Aggression   Moving

Redd Holding   Courting   Redd Maintenance
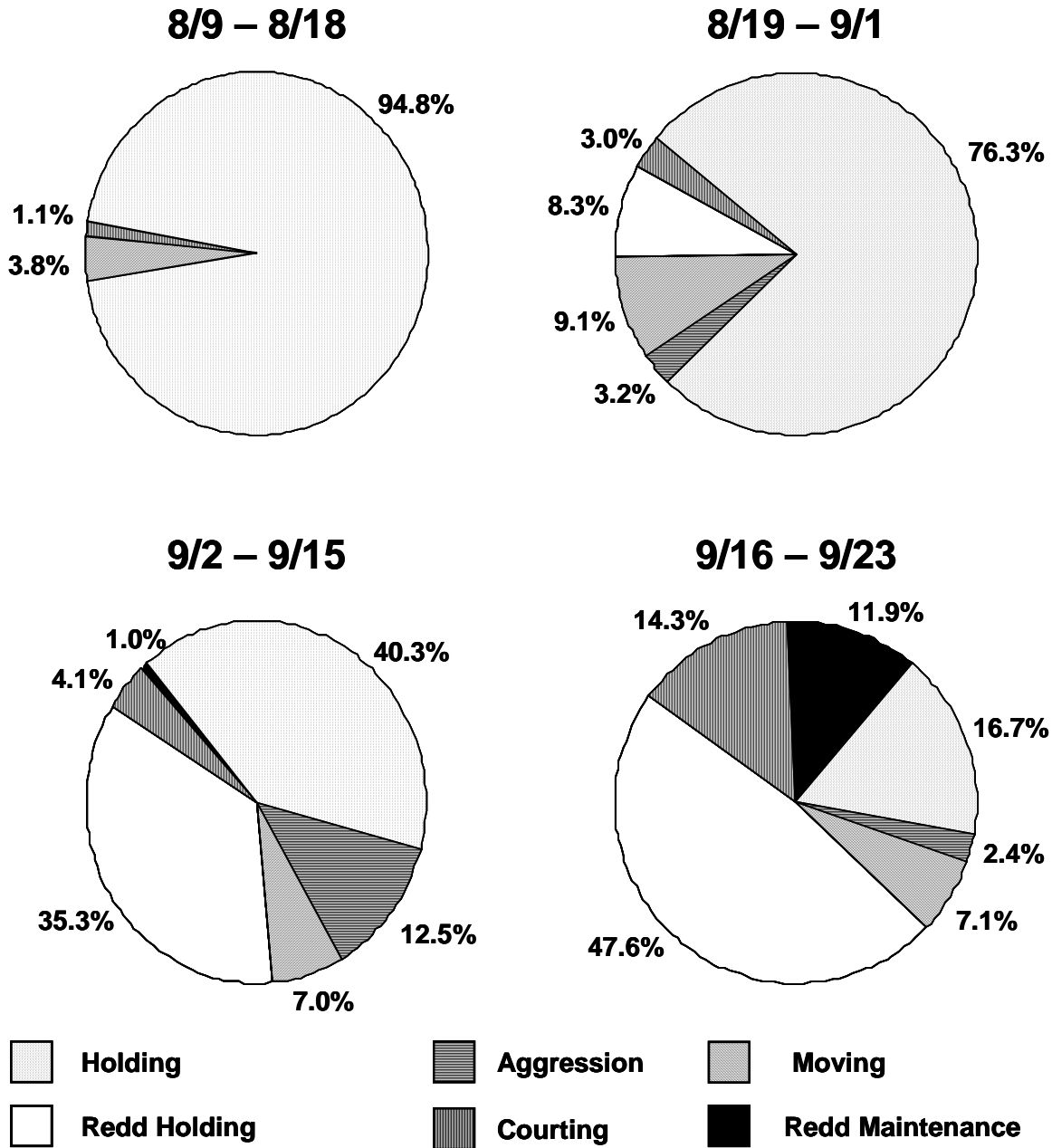
Figure 12. General behaviors of captive-reared Chinook salmon released into the West Fork Yankee Fork Salmon River in the summer of 2002. Data were collected during standardized observation intervals of 5 min.

Table 9.   Date of first redd initiation by captive-reared Chinook salmon in the West Fork Yankee Fork Salmon River, August–September 2002. Control fish (C) were held on ambient temperature well water (≈ 13.8°C) at the Eagle Fish Hatchery during final freshwater maturation, while treatment fish (T) were held on chilled water (≈ 9.0°C). Late arrivals (LA) were fish identified as maturing during a second sort and not transferred to the Eagle Fish Hatchery in time to be included in the temperature experiment, and were held on ambient water.

Initiation Date	Female Tag	Experimental Group
8/19/02	OO63	LA
8/22/02	OW80	C
8/23/02	OW65	C
8/26/02	OW80	C[a]
8/27/02	BW32	T
8/29/02	OO59	LA
8/29/02	OY21	C
8/30/02	OW98	C
8/30/02	OY47	C
9/1/02	BW02	T
9/1/02	BW32	T[a]
9/1/02	OO56	LA
9/1/02	YW76	T
9/2/02	BW23	T
9/2/02	OY23	C
9/3/02	OO67	LA
9/3/02	YW71	T
9/3/02	YW75	T
9/3/02	YW76	T[a]
9/4/02	OO56	LA[a]
9/4/02	YW77	T
9/5/02	BW12	T
9/5/02	YW71	T[a]
9/7/02	NO TAG	—
9/7/02	YW75	T[a]
9/8/02	BW15	T
9/8/02	YW51	T
9/9/02	YW72	T
9/10/02	OO97	LA
9/10/02	YW92	T
9/14/02	BW26	T
9/18/02	BW14	T
9/20/02	YW96	T

[a] Denotes second redd initiated by that female.

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For brood year 1997 females, 58.3% of females from the treatment group initiated redds compared to only 23.1% of those from the control group. Treatment group females from this brood year also had higher survival to the first date of spawning for their group (75.0% vs. 46.2%) and higher spawning participation (77.8% vs. 50.0%) from the surviving individuals. We observed similar results in brood year 1998 females, with 53.3% of those from the treatment group constructing redds compared to only 21.4% of the control fish. Furthermore, 61.5% of treatment fish that survived to the spawning period spawned, but only 33.3% of the surviving control fish constructed redds (Table 10). The small number of fish from this brood year transferred to Eagle after the main group as "late arrivals" were not included in the temperature experiment, but were released to spawn with the experimental fish and spawned at rates similar to chilled water fish.

Although statistical tests indicated control fish tended to spawn earlier than test fish (see Chilled Water Experiment above), more females from the chilled water group constructed redds than did those from the ambient group (Table 10). Additionally, exposure to chilled water appeared to have little effect on egg survival to the eyed stage of development in the LEM group (Appendix A). Ironically, the group having the highest overall point estimate of survival was the "late arrivals." Egg survival for these females averaged (geometric mean) 77.5% (n = 12, range 0.0–97.3%) versus 63.9% (n = 19, range 0.0–94.1%) in the chilled and 51.7% (n = 16, 0.0–94.8%) in the ambient groups (Appendix A.) However, these differences were not statistically significant (ANOVA, P = 0.107; SYSTAT 2000).

Even though more treatment fish constructed redds in comparison to control fish, all redds constructed by control fish were initiated prior to the mid-season spawning date of September 5, 2002. This apparent difference in redd initiation, however, was not significant between control and treatment fish using Yates's Corrected Chi-square test (P = 0.076, SYSTAT 2000). Since a 2.5°C reduction in temperature can produce a 12–20% decrease in basal metabolic rate (Berman and Quinn 1991 in Torgersen et al. 1999), it is plausible that control fish initiated spawning earlier simply due to the fact that the warmer water caused them to be more metabolically advanced than those from the control group. Considering our fish were held on water temperatures that deviated by ≈ 5°C, this finding also provides insight into the extended survival of treatment fish to initial spawning date (81.5%) held at a lower water temperature to control fish surviving to initial spawning date (55.6%; Table 10).

Initial tracking of fish after release into EFSR showed that most of the overall movements were generally downstream, possibly in response to the acclimation of a current (Figures 15, 16). However, several females did move upstream immediately after release. Subsequent samplings showed minimal movements by the majority of individuals of both sexes. In spite of this, a few individuals did show measurable amounts of movement (Figures 15, 16), but these events were limited and preceded by prolonged periods of holding. Average directional movements between sexes were quite uniform in both upstream and downstream changes between sampling dates.
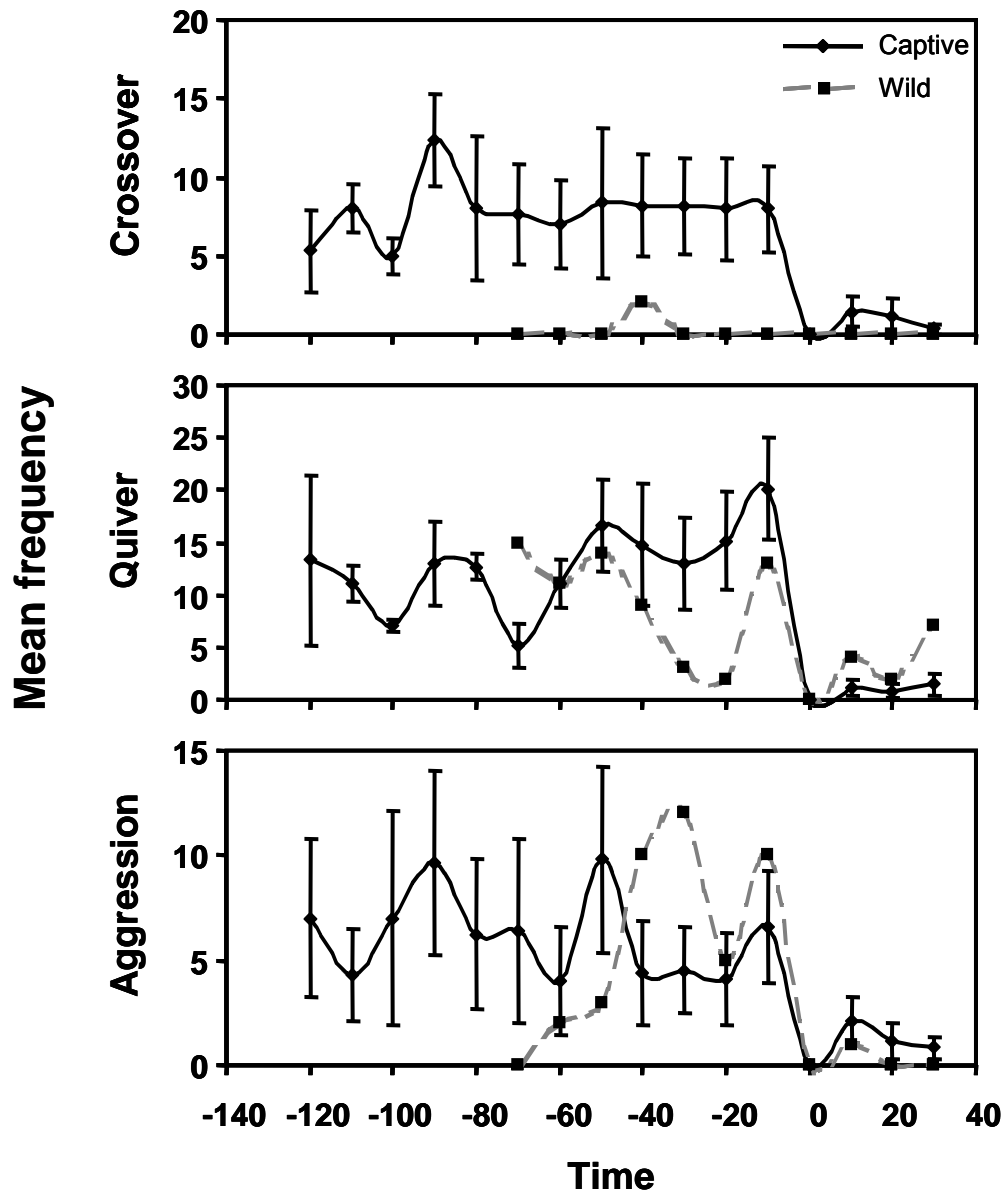
Figure 13. Frequency of courtship behavior and aggression in captive-reared (mean ± S.E.; n = 7) and wild (n = 1) Chinook salmon males observed spawning with captive-reared females in the West Fork Yankee Fork Salmon River, August–October 2002. Time zero is spawning, and negative and positive numbers are minutes prior to and post spawning, respectively.
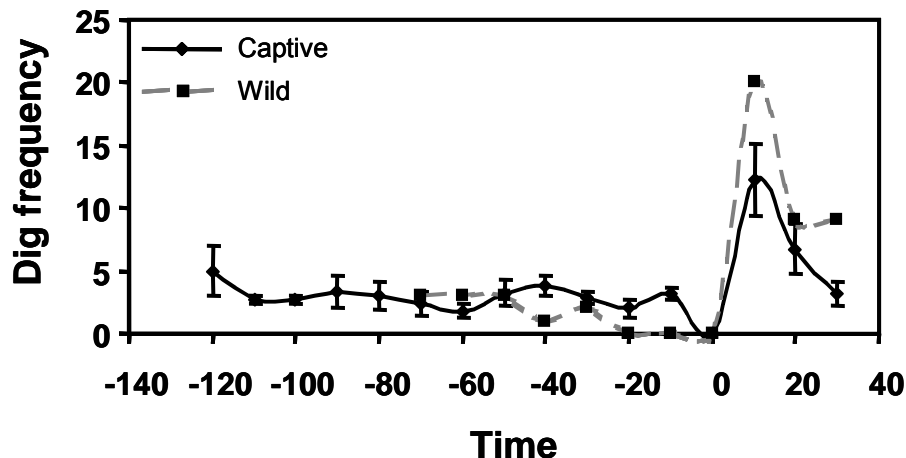
Figure 14. Frequency of digging by captive-reared female Chinook salmon observed spawning with captive-reared (mean + S.E.; n = 7) and wild (n = 1) males in the West Fork Yankee Fork Salmon River, August–October 2002. Time zero is spawning, and negative and positive numbers are minutes prior to and post spawning, respectively.

Production Estimation

Between August 2 and September 15, 2002, we collected DNA samples from wild Chinook parr in the WFYF. One hundred seventy-six parr were collected from 33 different sites established as areas of high productivity from previous years' spawning activities. Anal fin clips were collected and are stored at the Eagle Genetics Laboratory (Eagle, Idaho) for genetic analysis to determine parental lineage. Fork-length from all fish sampled averaged 63.4 mm (range, 40–87 mm). No mortalities were observed prior to release during the sampling events.

Eyed-eggs were also collected from a portion of the redds spawned by captive-reared Chinook salmon on October 8 and 9, 2002 to estimate egg fertilization rate and survival. We sampled 18 of the 33 redds produced by captive-reared females. Eggs were collected from 17 of the 18 redds sampled and the percent of clear eggs ranged from 0.0—100.0%. Of these 17 redds, nine had live (fertilized) eggs. Fertilization rates were similar to those reported in 2000 and 2001 (Venditti et. al.) except for redd CPT01WF (Table 11), which only had 33% fertilization. Of the three clear eggs extracted from this redd, two were polarized, which possibly affected the fertilization of the majority of the eggs. The single fertilized egg that was sampled may represent a proportion of those eggs that were not as ripe and thus more viable for fertilization.

Table 10. Results of brood year 1997, 1998, and 1997/1998 combined spawning initiation/activity for captive-reared Chinook salmon from two temperature groups (control = ambient, treatment = chilled) released to spawn volitionally in the West Fork Yankee Fork Salmon River in 2002. Late arrivals were fish determined to be maturing in a second maturation sort at the Manchester Marine Experimental Station and were not included in the experimental treatment. The median date of spawning activity was September 5, 2002. Those fish that initiated redd construction prior to that date were considered to have spawned in the first half. Those initiating redd construction after that date were considered to have spawned in the second half.

	Control	Treatment	Late arrivals	Total
Brood year 1997				
Number of females released	13	12	0	25
Number surviving to spawning	6	9	—	15
Proportion surviving to spawning	0.462	0.750	—	0.600
Number initiating spawning	3	7	0	10
Proportion initiating spawning	0.231	0.583	—	0.400
Proportion surviving initiating a redd	0.500	0.778	—	0.667
Number initiating a redd in 1st half	3	3	—	—
Proportion initiating a redd in 1st half	1.000	0.429	—	—
Number initiating a redd in 2nd half	0	4	—	—
Proportion initiating a redd in 2nd half	0.000	0.571	—	—
Brood year 1998				
Number of females released	14	15	8	37
Number surviving to spawning	9	13	6	28
Proportion surviving to spawning	0.643	0.867	0.750	0.757
Number initiating a redd	3	8	5	16
Proportion initiating a redd	0.214	0.533	0.625	0.432
Proportion surviving initiating a redd	0.333	0.615	0.833	0.571
Number initiating a redd in 1st half	3	4	4	—
Proportion initiating a redd in 1st half	1.000	0.500	0.800	—
Number initiating a redd in 2nd half	0	4	1	—
Proportion initiating a redd in 2nd half	0.000	0.500	0.200	—
Brood years combined				
Number of females released	27	27	8	62
Number initiating spawning	6	15	5	26
Proportion initiating spawning	0.097	0.242	0.081	0.419
Number initiating spawning in 1st half	6	7	4	17
Proportion initiating spawning in 1st half	1.000	0.467	0.800	0.654
Proportion initiating spawning in 1st half	1.000	0.467	0.800	0.654
Number initiating spawning in 2nd half	0	8	1	9
Proportion initiating spawning in 2nd half	0.000	0.533	0.200	0.346
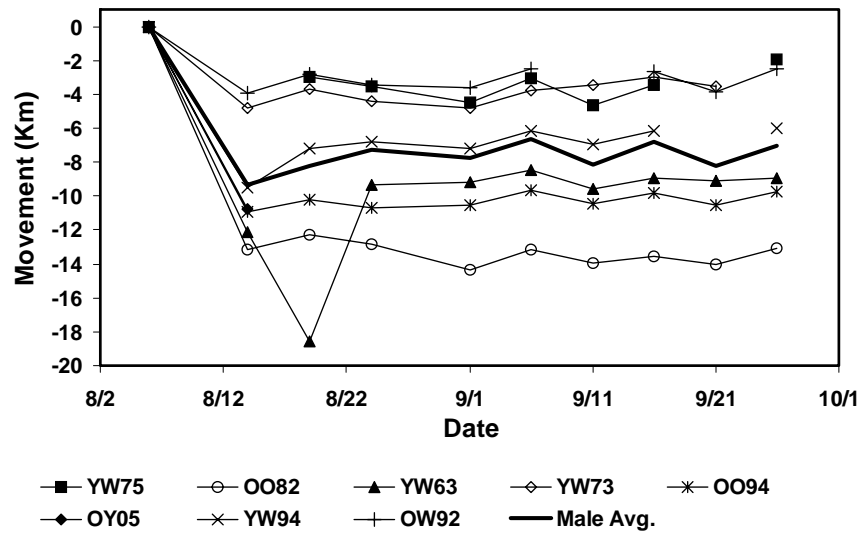
Figure 15. Movement of radio-tagged male Chinook salmon from initial point of release (Distance = 0 Km) within the East Fork Salmon River during the summer of 2002. Positive and negative slopes represent upstream and downstream movements, respectively, from previous tracking date.
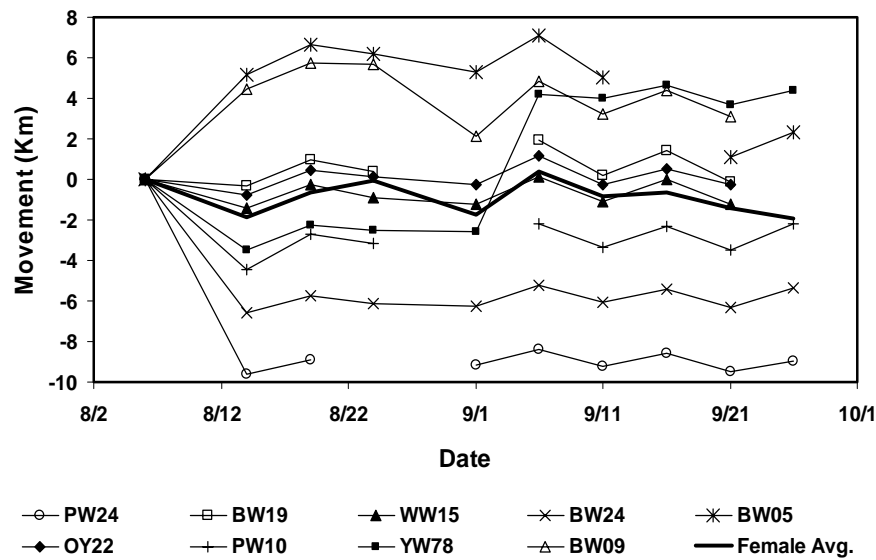
Figure 16. Movement of radio-tagged female Chinook salmon from initial point of release (Distance = 0 Km) within the East Fork Salmon River during the summer of 2002. Positive and negative slopes represent upstream and downstream movements, respectively, from previous tracking date.

We used information obtained by sampling captive-spawned redds and from hatchery spawning activities to estimate the total number of eyed-eggs produced by captive-reared Chinook salmon in the WFYF in 2002 using the formula below. Our fecundity estimate was based on values obtained from captive-reared LEM females spawned at Eagle in 2002, which averaged 2,011 eggs/female (Appendix A). Additionally, the redd with only 33.3% fertilization was omitted from the computation of overall fertilization rate due to the poor quality of the eggs observed in that redd and because fertilization in that redd differed so drastically from what was observed in the other redds. Applying the following formula to these data provides an estimate of 22,900 eyed-eggs produced by program fish:

Eyed-eggs = Number of redds X Mean fecundity X Proportion viable eggs X Proportion fertilized.

Table 11.   Results from sampling redds spawned by captive-reared females in the West Fork Yankee Fork Salmon River. Treatment and control fish refer to those held on chilled and ambient temperature water, respectively, at the Eagle Fish Hatchery during final maturation. Eggs were collected October 8-9, 2002.

Redd	Female	BY	Size	Treatment	Clear	Opaque	Proportion Clear	Proportion Fertilized
CJA07WF	YW76	98	S	T	10	0	1.00	1.00
CJA11WF	YW71	98	L	T	11	1	0.92	1.00
CPT02WF	YW75	98	S	T	25	4	0.86	1.00
JBH15WF	YW72	98	L	T	9	4	0.69	1.00
CCW01WF	UNK.	—	—	—	30	18	0.63	0.97
JBH08WF	OW98	98	L	C	18	11	0.62	1.00
TRR06WF	OO59	98	—	LA	15	10	0.60	1.00
JBH03WF	OW80	98	L	C	21	22	0.49	1.00
CPT01WF	OO??	98	—	LA	3	34	0.08	0.33
JBH11WF	BW02	97	S	T	0	17	0.00	N/A
DAV17WF	BW23	97	S	T	0	14	0.00	N/A
TRR15WF	BW26	97	S	T	0	184	0.00	N/A
JTG06WF	BW26	97	S	T	0	30	0.00	N/A
TRR14WF	UNK.	—	—	—	0	19	0.00	N/A
CJA10WF	OO56	98	—	LA	0	217	0.00	N/A
JTG02WF	OW65	98	S	C	0	108	0.00	N/A
DAV16WF	OY23	97	L	C	0	69	0.00	N/A
JBH05WF	UNK.	—	—	—	0	0	N/A	N/A

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APPENDICES

Appendix A. Summary of spawning activities involving captive-reared, Lemhi River Chinook salmon at the Eagle Fish Hatchery in 2002. Fish known to be maturing were separated into two groups; one held on chilled water (test), one on ambient temperature well water (control), and to determine the effect of temperature on maturation timing. The number of fish in the two groups was determined by the number that could be maintained on chilled water. Fish beyond this number were maintained on ambient water but were treated as a separate group for analysis. Both males and females from brood years (BY) 1997 and 1998 matured in 2002 along with males from BY 1999. Overall survival for individual females was computed using the geometric mean survival from individual subfamilies produced by that female.

Spawn Date	Female Origin	Female BY	Female Temp. Group*	Female Weight	Female Fecundity	Male Origin	Male BY	Male Temp. Group*	Green Eggs	Eyed-Eggs	Subfamily Survival	Geometric Mean Survival
9/16	NMFS	98	Ambient[1]	2140	1970	NMFS	99	Ambient[1]	443	189	0.427	0.427
9/16	NMFS	98	Ambient[2]	2260	2370	NMFS	99	Ambient[1]	352	224	0.636	0.636
9/16	NMFS	98	Ambient[2]	1512	2361	NMFS	99	Ambient[2]	770	656	0.852	0.826
9/16	NMFS	98	Ambient[2]	1512	2361	NMFS	99	Ambient[2]	761	610	0.802	
9/16	NMFS	98	Ambient[2]	1512	2361	NMFS	99	Ambient[2]	711	586	0.824	
9/16	NMFS	98	Ambient[2]	1418	1916	NMFS	99	Ambient[2]	824	752	0.913	0.931
9/16	NMFS	98	Ambient[2]	1418	1916	NMFS	99	Ambient[2]	836	794	0.950	
9/16	NMFS	98	Ambient[2]	1085	2648	NMFS	99	Ambient[2]	576	507	0.880	0.886
9/16	NMFS	98	Ambient[2]	1085	2648	NMFS	99	Ambient[2]	558	498	0.892	
9/17	NMFS	98	Ambient[2]	906	734	NMFS	99	Ambient[2]	358	348	0.972	0.963
9/17	NMFS	98	Ambient[2]	906	734	NMFS	99	Ambient[2]	352	336	0.955	
9/20	NMFS	98	Chilled	1935	2080	NMFS	98	Chilled	676	627	0.928	0.941
9/20	NMFS	98	Chilled	1935	2080	NMFS	99	Chilled	671	640	0.954	
9/20	NMFS	98	Chilled	1935	2080	NMFS	99	Chilled	655	617	0.942	
9/23	NMFS	98	Ambient[2]	1851	1815	NMFS	99	Ambient[2]	583	532	0.913	0.956
9/23	NMFS	98	Ambient[2]	1851	1815	EAGLE	99	Ambient[2]	548	533	0.973	
9/23	NMFS	98	Ambient[2]	1851	1815	EAGLE	99	Ambient[2]	531	523	0.985	
9/23	NMFS	98	Chilled	1741	1148	NMFS	98	Chilled	415	325	0.783	0.807
9/23	NMFS	98	Chilled	1741	1148	NMFS	97	Chilled	417	347	0.832	
9/23	NMFS	97	Ambient[1]	1851	1124	NMFS	99	Ambient[1]	343	160	0.466	0.506
9/23	NMFS	97	Ambient[1]	1851	1124	NMFS	97	Ambient[1]	333	165	0.495	
9/23	NMFS	97	Ambient[1]	1851	1124	NMFS	98	Ambient[1]	319	179	0.561	
9/26	NMFS	98	Chilled	2168	978	NMFS	99	Chilled	335	174	0.519	0.496
9/26	NMFS	98	Chilled	2168	978	NMFS	99	Chilled	245	98	0.400	
9/26	NMFS	98	Chilled	2168	978	NMFS	98	Chilled	325	191	0.588	
9/26	NMFS	97	Chilled	3400	4348	NMFS	99	Chilled	806	229	0.284	0.337
9/26	NMFS	97	Chilled	3400	4348	NMFS	99	Chilled	841	296	0.352	
9/26	NMFS	97	Chilled	3400	4348	NMFS	99	Chilled	837	302	0.361	
9/26	NMFS	97	Chilled	3400	4348	NMFS	97	Chilled	760	271	0.357	
9/26	NMFS	97	Chilled	3400	4348	NMFS	98	Chilled	915	307	0.336	
9/26	NMFS	98	Chilled	2597	1308	NMFS	98	Chilled	391	167	0.427	0.389
9/26	NMFS	98	Chilled	2597	1308	NMFS	99	Chilled	428	170	0.397	

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Spawn Date	Female Origin	Female BY	Female Temp. Group*	Female Weight	Female Fecundity	Male Origin	Male BY	Male Temp. Group*	Green Eggs	Eyed-Eggs	Subfamily Survival	Geometric Mean Survival
9/26	NMFS	98	Chilled	2597	1308	NMFS	97	Chilled	390	135	0.346	
9/26	NMFS	97	Chilled	1500	2979	NMFS	98	Chilled	702	512	0.729	0.738
9/26	NMFS	97	Chilled	1500	2979	NMFS	99	Chilled	757	560	0.740	
9/26	NMFS	97	Chilled	1500	2979	NMFS	99	Chilled	611	453	0.741	
9/26	NMFS	97	Chilled	1500	2979	NMFS	99	Chilled	755	561	0.743	
9/26	NMFS	98	Chilled	1301	1564	NMFS	99	Chilled	489	234	0.479	0.531
9/26	NMFS	98	Chilled	1301	1564	NMFS	97	Chilled	469	233	0.497	
9/26	NMFS	98	Chilled	1301	1564	NMFS	98	Chilled	402	253	0.629	
9/26	NMFS	98	Chilled	2033	2167	NMFS	98	Chilled	687	656	0.955	0.935
9/26	NMFS	98	Chilled	2033	2167	NMFS	98	Chilled	707	674	0.953	
9/26	NMFS	98	Chilled	2033	2167	NMFS	99	Chilled	699	628	0.898	
9/26	NMFS	98	Chilled	1551	1648	NMFS	98	Chilled	754	656	0.870	0.837
9/26	NMFS	98	Chilled	1551	1648	NMFS	98	Chilled	793	639	0.806	
9/26	NMFS	98	Chilled	1206	1317	NMFS	98	Chilled	645	605	0.938	0.918
9/26	NMFS	98	Chilled	1206	1317	NMFS	98	Chilled	651	585	0.899	
9/26	NMFS	98	Ambient[1]	1189	1322	NMFS	99	Ambient[1]	624	497	0.796	0.830
9/26	NMFS	98	Ambient[1]	1189	1322	NMFS	99	Ambient[2]	629	544	0.865	
9/26	NMFS	97	Ambient[1]	1645	1736	NMFS	99	Ambient[1]	578	541	0.936	0.948
9/26	NMFS	97	Ambient[1]	1645	1736	NMFS	99	Ambient[1]	569	542	0.953	
9/26	NMFS	97	Ambient[1]	1645	1736	NMFS	98	Ambient[2]	579	553	0.955	
9/26	NMFS	98	Ambient[1]	1508	1587	NMFS	99	Ambient[2]	810	641	0.791	0.769
9/26	NMFS	98	Ambient[1]	1508	1587	NMFS	99	Ambient[2]	798	597	0.748	
9/26	NMFS	98	Ambient[1]	1289	1596	NMFS	99	Ambient[2]	699	442	0.632	0.607
9/26	NMFS	98	Ambient[1]	1289	1596	NMFS	99	Ambient[2]	708	412	0.582	
9/26	NMFS	98	Ambient[1]	2195	2413	NMFS	99	Ambient[2]	710	610	0.859	0.857
9/26	NMFS	98	Ambient[1]	2195	2413	NMFS	99	Ambient[2]	699	587	0.840	
9/26	NMFS	98	Ambient[1]	2195	2413	NMFS	97	Ambient[1]	687	599	0.872	
9/26	NMFS	98	Ambient[1]	607	777	NMFS	99	Ambient[2]	378	172	0.455	0.440
9/26	NMFS	98	Ambient[1]	607	777	NMFS	99	Ambient[2]	392	167	0.426	
9/26	NMFS	98	Ambient[1]	1140	1303	NMFS	99	Ambient[1]	643	576	0.896	0.897
9/26	NMFS	98	Ambient[1]	1140	1303	NMFS	98	Ambient[1]	638	573	0.898	
9/26	NMFS	98	Ambient[2]	1334	1022	NMFS	99	Ambient[2]	770	567	0.736	0.736
10/1	NMFS	98	Ambient[1]	1550	1610	NMFS	99	Ambient[2]	494	0	0.000	0.000
10/1	NMFS	98	Ambient[1]	1550	1610	NMFS	99	Ambient[2]	500	0	0.000	
10/1	NMFS	98	Ambient[1]	1550	1610	NMFS	99	Ambient[2]	514	0	0.000	
10/1	NMFS	98	Ambient[1]	1380	643	NMFS	99	Ambient[2]	304	50	0.164	0.180
10/1	NMFS	98	Ambient[1]	1380	643	NMFS	99	Ambient[2]	305	60	0.197	
10/1	EAGLE	98	Ambient[2]	528	1190	NMFS	99	Ambient[2]	205	0	0.000	0.000
10/4	NMFS	98	Ambient[2]	1979	2318	NMFS	99	Ambient[2]	743	658	0.886	0.885
10/4	NMFS	98	Ambient[2]	1979	2318	NMFS	99	Ambient[2]	741	667	0.900	
10/4	NMFS	98	Ambient[2]	1979	2318	NMFS	99	Ambient[2]	752	653	0.868	

Spawn Date	Female Origin	Female BY	Female Temp. Group*	Female Weight	Female Fecundity	Male Origin	Male BY	Male Temp. Group*	Green Eggs	Eyed-Eggs	Subfamily Survival	Geometric Mean Survival
10/4	NMFS	97	Ambient[1]	1305	1766	NMFS	99	Ambient[2]	790	0	0.000	0.000
10/4	NMFS	98	Ambient[2]	1173	1812	NMFS	99	Ambient[1]	561	285	0.508	0.551
10/4	NMFS	98	Ambient[2]	1173	1812	NMFS	99	Ambient[2]	475	288	0.606	
10/4	NMFS	98	Ambient[2]	1173	1812	NMFS	99	Ambient[2]	553	301	0.544	
10/4	NMFS	98	Chilled	1338	2354	NMFS	99	Chilled	706	577	0.817	0.806
10/4	NMFS	98	Chilled	1338	2354	NMFS	98	Chilled	713	574	0.805	
10/4	NMFS	98	Chilled	1338	2354	NMFS	99	Chilled	694	552	0.795	
10/4	NMFS	98	Chilled	1858	2274	NMFS	99	Chilled	733	483	0.659	0.627
10/4	NMFS	98	Chilled	1858	2274	NMFS	98	Chilled	742	434	0.585	
10/4	NMFS	98	Chilled	1858	2274	NMFS	99	Chilled	721	462	0.641	
10/4	NMFS	98	Chilled	1690	1975	NMFS	99	Chilled	634	478	0.754	0.715
10/4	NMFS	98	Chilled	1690	1975	NMFS	99	Chilled	641	455	0.710	
10/4	NMFS	98	Chilled	1690	1975	NMFS	99	Chilled	638	436	0.683	
10/4	NMFS	98	Chilled	1187	1585	NMFS	99	Chilled	437	361	0.826	0.858
10/4	NMFS	98	Chilled	1187	1585	NMFS	99	Chilled	433	385	0.889	
10/4	NMFS	98	Chilled	1187	1585	NMFS	99	Chilled	433	373	0.861	
10/4	NMFS	98	Chilled	1900	3068	NMFS	99	Chilled	794	199	0.251	0.290
10/4	NMFS	98	Chilled	1900	3068	NMFS	99	Chilled	770	234	0.304	
10/4	NMFS	98	Chilled	1900	3068	NMFS	98	Chilled	776	249	0.321	
10/4	NMFS	98	Chilled	861	480	NMFS	99	Chilled	315	102	0.324	0.324
10/4	NMFS	98	Chilled	869	892	NMFS	98	Chilled	413	278	0.673	0.693
10/4	NMFS	98	Chilled	869	892	NMFS	99	Chilled	423	302	0.714	
10/8	NMFS	98	Ambient[1]	2663	3532	NMFS	99	Ambient[2]	876	798	0.911	0.904
10/8	NMFS	98	Ambient[1]	2663	3532	NMFS	98	Ambient[1]	849	778	0.916	
10/8	NMFS	98	Ambient[1]	2663	3532	NMFS	97	Ambient[1]	874	766	0.876	
10/8	NMFS	98	Ambient[1]	2663	3532	NMFS	99	Ambient[1]	862	788	0.914	
10/8	NMFS	98	Ambient[2]	1507	2365	NMFS	98	Ambient[1]	776	740	0.954	0.951
10/8	NMFS	98	Ambient[2]	1507	2365	NMFS	99	Ambient[1]	781	722	0.924	
10/8	NMFS	98	Ambient[2]	1507	2365	NMFS	99	Ambient[1]	758	739	0.975	
10/8	NMFS	97	Ambient[1]	1287	2033	NMFS	99	Ambient[1]	408	3	0.007	0.004
10/8	NMFS	97	Ambient[1]	1287	2033	NMFS	99	Ambient[2]	407	1	0.002	
10/8	NMFS	98	Chilled	1487	1531	NMFS	99	Chilled	497	441	0.887	0.901
10/8	NMFS	98	Chilled	1487	1531	NMFS	97	Chilled	491	431	0.878	
10/8	NMFS	98	Chilled	1487	1531	NMFS	98	Chilled	541	508	0.939	
10/11	NMFS	98	Chilled	1510	2176	NMFS	98	Chilled	676	0	0.000	0.000
10/11	NMFS	98	Chilled	1510	2176	NMFS	99	Chilled	691	0	0.000	
10/11	NMFS	98	Chilled	1510	2176	NMFS	99	Chilled	663	0	0.000	
10/11	NMFS	98	Ambient[1]	1606	2668	NMFS	99	Ambient[1]	856	12	0.014	0.017
10/11	NMFS	98	Ambient[1]	1606	2668	NMFS	97	Ambient[1]	846	17	0.020	
10/11	NMFS	98	Ambient[1]	1606	2668	NMFS	99	Ambient[1]	821	14	0.017	
10/11	NMFS	98	Ambient[2]	1357	1706	NMFS	99	Ambient[2]	576	564	0.979	0.973

Appendix A. Continued.

Spawn Date	Female Origin	Female BY	Female Temp. Group*	Female Weight	Female Fecundity	Male Origin	Male BY	Male Temp. Group*	Green Eggs	Eyed-Eggs	Subfamily Survival	Geometric Mean Survival
10/11	NMFS	98	Ambient[2]	1357	1706	NMFS	97	Ambient[1]	556	538	0.968	
10/11	NMFS	98	Ambient[2]	1357	1706	NMFS	99	Ambient[2]	556	540	0.971	
10/11	NMFS	98	Ambient[1]	2066	2881	NMFS	99	Ambient[1]	489	424	0.867	0.893
10/11	NMFS	98	Ambient[1]	2066	2881	NMFS	99	Ambient[2]	495	439	0.887	
10/11	NMFS	98	Ambient[1]	2066	2881	NMFS	99	Ambient[1]	498	461	0.926	

[1] Fish held on ambient temperature water acting as control fish in determining the effect of temperature on maturation.
[2] Fish held on ambient temperature water not included in analyses determining the effect of temperature on maturation.

Appendix B. Summary of fish transfers conducted by the Chinook salmon captive rearing project during 2002. LEM–Lemhi River, WFYF–West Fork Yankee Fork Salmon River, EFSR–East Fork Salmon River, MAN–Manchester Marine Experimental Station, EAG–Eagle Fish Hatchery. NP, NE and SN refer to natural parr, natural egg, and safety net groups, respectively.

Source Stream	BY	EAG to MAN	Transfer Date	MAN to EAG	Transfer Date	EAG to WFYF	Transfer Date	EAG to EFSR	Transfer Date
LEM-NP	1997			10	04/23				
LEM-NP	1998			41	04/23				
LEM-NP	1998			15	06/11				
LEM-NE	1999			35	04/23				
LEM-NE	1999			6	06/11				
WFYF-NP	1997			33	04/23	27	08/08		
WFYF-NP	1998			55	04/23	56	08/08		
WFYF-NP	1998			10	06/11				
WFYF-SN	1999			68	04/23	76	08/08		
WFYF-SN	1999			1	06/11				
WFYF-NE	2000	9	04/25			56	08/08		
WFYF-NE	2000	194	05/02						
EFSR-NP	1998			23	04/23			29	08/06
EFSR-NP	1998			7	06/11				
EFSR-SN	1998			7	04/23			14	08/06
EFSR-SN	1998			11	06/11			3	08/07
EFSR-NE+SN	1999			23	04/23			11	08/06
EFSR-NE+SN	1999			11	06/11			32	08/07
EFSR-NE	2000	10	04/25					41	08/07
EFSR-NE	2000	369	05/02						

Appendix C. Tag and identification summary for captive-reared Chinook salmon released for volitional spawning in the West Fork Yankee Fork Salmon River (WFYF) and the East Fork Salmon River (EFSR). Fish were disc-tagged for visual identification using unique color and number combinations and radio-tag frequency (frequency = Freq.). A portable ultrasound unit was used on maturing fish reared at the Manchester Marine Experimental Station (MAN) to determine sex, and classified as undetermined–U, female–F, or male–M. Ultrasound was not used on fish reared at the Eagle Fish Hatchery (EAG). Disc-tag colors include W–white, B–blue, Y–yellow, O–orange, and P–pink. Treatment group in the WFYF reared at MAN refers to the temperature experienced during freshwater maturation at EAG. Test fish (T) were held on chilled water, ($\approx 9.0°C$) control fish (C) were held on ambient water ($\approx 13.5°C$), and late arrivals (LA) those fish transferred to freshwater about six weeks later than the others were held on ambient water. Fish heavier than the group mean for their stock and brood year (BY) were classified as large (L), while those lighter were considered small (S). Fish from the EFSR, WFYF-LA, and those reared at EAG were not included in the temperature study.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
3D9.1BF0ED12E0	1998			487	B/W	27		EFSR			EAG
3D9.1BF0DFC592	1998			1010	O/Y	24		EFSR			EAG
3D9.1BF0E0DC2F	1998			1265	O/Y	27		EFSR			EAG
3D9.1BF0EC49AA	1999			1356	O/W	55		EFSR			EAG
3D9.1BF0EC46CB	1999			0807	O/W	75		EFSR			EAG
3D9.1BF0ECDFE1	1999			1047	O/W	78		EFSR			EAG
3D9.1BF0ECD729	1999			855	O/W	79		EFSR			EAG
3D9.1BF0ED3F27	1999			900	O/Y	12		EFSR			EAG
3D9.1BF0ED20A1	1999			1173	Y/W	58		EFSR			EAG
3D9.1BF0EC4BE6	1999			1571	Y/W	64		EFSR			EAG
3D9.1BF0EC451A	1999			1879	Y/W	69		EFSR			EAG
3D9.1BF0EE350E	1999			1330	Y/W	85		EFSR			EAG
3D9.1BF0EE64AF	1999			1694	Y/W	95		EFSR			EAG
3D9.1BF11AEDE2	2000	M		200	R/R			EFSR			EAG
3D9.1BF11AE48C	2000	M		200	R/R			EFSR			EAG
3D9.1BF11AB333	2000	M		100	R/R			EFSR			EAG
3D9.1BF11ADBEF	2000	M		100	R/R			EFSR			EAG
3D9.1BF11ADDDF	2000	M		200	R/R			EFSR			EAG
3D9.1BF11ADD80	2000	M		100	R/R			EFSR			EAG
3D9.1BF11AA6B9	2000	M		100	R/R			EFSR			EAG
3D9.1BF11AAC3A	2000	M		100	R/R			EFSR			EAG
3D9.1BF11AEBD7	2000	M		100	R/R			EFSR			EAG
3D9.1BF11AE63F	2000	M		100	R/R			EFSR			EAG
....	2000	M		100	R/R			EFSR			EAG
3D9.1BF11AE748	2000	M		95	R/R			EFSR			EAG
3D9.1BF11BA1A4	2000	M		142	R/R			EFSR			EAG
3D9.1BF11B8449	2000	M		141	R/R			EFSR			EAG
3D9.1BF11AB4DF	2000	M		108	R/R			EFSR			EAG

Appendix C. Continued.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
3D9.1BF11ADDB0	2000	M		101	R/R			EFSR			EAG
3D9.1BF11AD98C	2000	M		128	R/R			EFSR			EAG
3D9.1BF11AE09B	2000	M		167	R/R			EFSR			EAG
3D9.1BF11AED63	2000	M		179	R/R			EFSR			EAG
3D9.1BF11AB511	2000	M		68	R/R			EFSR			EAG
3D9.1BF11AF248	2000	M		106	R/R			EFSR			EAG
3D9.1BF11AF789	2000	M		135	R/R			EFSR			EAG
3D9.1BF11ADF63	2000	M		137	R/R			EFSR			EAG
3D9.1BF11E9A95	2000	M		148	R/R			EFSR			EAG
3D9.1BF11AB655	2000	M		169	R/R			EFSR			EAG
3D9.1BF11AD24E	2000	M		174	R/R			EFSR			EAG
3D9.1BF11AD98E	2000	M		119	R/R			EFSR			EAG
3D9.1BF11AE6A8	2000	M		140	R/R			EFSR			EAG
3D9.1BF11ADDD3	2000	M		153	R/R			EFSR			EAG
3D9.1BF11AF8C1	2000	M		118	R/R			EFSR			EAG
3D9.1BF11AA57E	2000	M		165	R/R			EFSR			EAG
3D9.1BF11AE296	2000	M		164	R/R			EFSR			EAG
3D9.1BF11EB16B	2000	M		196	R/R			EFSR			EAG
3D9.1BF11ACBAF	2000	M		107	R/R			EFSR			EAG
3D9.1BF11AB163	2000	M		107	R/R			EFSR			EAG
3D9.1BF11ADFBA	2000	M		116	R/R			EFSR			EAG
3D9.1BF11AE5DB	2000	M		109	R/R			EFSR			EAG
3D9.1BF11AE0FC	2000	M		155	R/R			EFSR			EAG
3D9.1BF11AE221	2000	M		147	R/R			EFSR			EAG
3D9.1BF11EA86A	2000	M		164	R/R			EFSR			EAG
3D9.1BF11ADF0E	2000	M		140	R/R			EFSR			EAG
3D9.1BF0EC5A6E	1998	F	453	1502	B/W	0		EFSR			MAN
3D9.1BF0ED4114	1998	F	561	2895	B/W	1		EFSR			MAN
3D9.1BF0ED43D5	1998	F	498	2345	B/W	5	1.702	EFSR			MAN
3D9.1BF0ED0779	1998	F	515	2420	B/W	6	1.744	EFSR			MAN
3D9.1BF0DFF13D	1998	UNK	478	2400	B/W	7		EFSR			MAN
3D9.1BF0E11FC0	1998	F	533	2959	B/W	8		EFSR			MAN
3D9.1BF0EC5E23	1998	F	577	2923	B/W	9	1.313	EFSR			MAN
3D9.1BF0EC3D72	1998	M	393	892	B/W	10		EFSR			MAN
3D9.1BF0EC3C54	1998	F	565	2614	B/W	13		EFSR			MAN
3D9.1BF0EC32AA	1998	M	470	1526	B/W	16	1.563	EFSR			MAN
3D9.1BF0EC3F97	1998	F	557	2597	B/W	18		EFSR			MAN
3D9.1BF0ED4BC0	1998	F	595	3097	B/W	19	1.212	EFSR			MAN
3D9.1BF0ED167F	1998	F	503	2160	B/W	22		EFSR			MAN
3D9.1BF0ED4E06	1998	F	525	2402	B/W	24	1.802	EFSR			MAN
3D9.1BF0EC480E	1998	F	557	2988	B/W	25		EFSR			MAN
3D9.1BF0ECDD9E	1998	M	485	2074	B/W	30		EFSR			MAN
3D9.1BF0ED2B13	1998	UNK	523	2187	B/W	39		EFSR			MAN

Appendix C. Continued.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
3D9.1BF0EC3EF6	1998	F	509	2095	B/W	40		EFSR			MAN
3D9.1BF0EC564E	1998	M	456	1348	B/W	41		EFSR			MAN
3D9.1BF0ED361D	1998	F	565	2761	B/W	44		EFSR			MAN
3D9.1BF0ED4DF0	1998	UNK	420	1498	B/W	46		EFSR			MAN
3D9.1BF0EC365B	1998	F	599	3147	B/W	47	1.252	EFSR			MAN
3D9.1BF0EC3204	1998	M	472	1666	B/W	49		EFSR			MAN
3D9.1BF0E0D67A	1998	M	515	2032	O/Y	5	1.842	EFSR			MAN
3D9.1BF0DF3DED	1998	F	391	771	O/Y	20		EFSR			MAN
3D9.1BF0E0226B	1998	F	431	1025	O/Y	22	1.682	EFSR			MAN
3D9.1BF0DF3BA1	1998	F	464	1742	O/Y	25	1.974	EFSR			MAN
3D9.1BF0DFF448	1998	F	405	740	O/Y	30		EFSR			MAN
3D9.1BF0DF242F	1998	M	346	548	O/Y	90		EFSR			MAN
3D9.1BF0E022B8	1998	F	533	2729	P/W	1		EFSR			MAN
3D9.1BF0DFEA8B	1998	F	541	2174	P/W	6	1.644	EFSR			MAN
3D9.1BF0E0DE0D	1998	F	448	1329	P/W	8		EFSR			MAN
3D9.1BF0DEFB61	1998	F	445	1200	P/W	9		EFSR			MAN
3D9.1BF0DFDA89	1998	F	515	2489	P/W	10	1.604	EFSR			MAN
3D9.1BF0DF1886	1998	F	572	2723	P/W	18		EFSR			MAN
3D9.1BF0DFE6A3	1998	F	490	1397	P/W	19		EFSR			MAN
3D9.1BF0DFE8C7	1998	F	608	3572	P/W	20		EFSR			MAN
3D9.1BF0DFE958	1998	F	555	2900	P/W	24	0.883	EFSR			MAN
3D9.1BF0DF1DD3	1998	F	425	979	P/W	30		EFSR			MAN
3D9.1BF0EC5060	1998	F	519	2174	W/W	15	1.894	EFSR			MAN
3D9.1BF0DF4728	1998	M	391	1240	W/W	22		EFSR			MAN
3D9.1BF0EC3AFD	1998	F	538	2388	W/W	25		EFSR			MAN
3D9.1BF0EE67C0	1998	M	423	1143	W/W	30		EFSR			MAN
3D9.1BF0ED20FC	1998	F	458	1667	W/W	36		EFSR			MAN
3D9.1BF0EE6641	1998	F	415	1438	W/W	41		EFSR			MAN
3D9.1BF0EC45C2	1998	F	477	2160	Y/W	70		EFSR			MAN
3D9.1BF0ED3A41	1999	M	387	912	O/O	51		EFSR			MAN
3D9.1BF0ED5655	1999	M	343	715	O/O	55		EFSR			MAN
3D9.1BF0ECCBCC	1999	M	393	933	O/O	64		EFSR			MAN
3D9.1BF0EC593D	1999	M	387	776	O/O	65		EFSR			MAN
3D9.1BF0ED4D41	1999	M	379	744	O/O	76		EFSR			MAN
3D9.1BF0EC4514	1999	M	459	1323	O/O	82	1.954	EFSR			MAN
3D9.1BF0EC3965	1999	M	395	928	O/O	84		EFSR			MAN
3D9.1BF0ED0776	1999	M	412	950	O/O	88		EFSR			MAN
3D9.1BF0ECD2C8	1999	M	421	1143	O/O	92		EFSR			MAN
3D9.1BF0EC4FC9	1999	M	322	444	O/O	93		EFSR			MAN
3D9.1BF0EC46D8	1999	M	451	1337	O/O	94	1.764	EFSR			MAN
3D9.1BF0EE64C0	1999	M	392	801	O/O	95		EFSR			MAN
3D9.1BF0EE1677	1999	M	383	940	O/W	42		EFSR			MAN
3D9.1BF0EE68C0	1999	M	329	595	O/W	56		EFSR			MAN

Appendix C. Continued.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
3D9.1BF0ED49A0	1999	M	370	846	O/W	59		EFSR			MAN
3D9.1BF0EC30F3	1999	M	373	846	O/W	67		EFSR			MAN
3D9.1BF0EC39F5	1999	M	394	942	O/W	85		EFSR			MAN
3D9.1BF0EC59DF	1999	M	410	1251	O/W	92	1.583	EFSR			MAN
3D9.1BF0EE75A3	1999	M	362	743	O/W	94		EFSR			MAN
3D9.1BF0EC3162	1999	M	373	746	Y/W	52		EFSR			MAN
3D9.1BF0EE33BA	1999	F	413	969	Y/W	54	1.514	EFSR			MAN
3D9.1BF0ED4BAB	1999	M	333	549	Y/W	56		EFSR			MAN
3D9.1BF0EE0D7A	1999	M	410	1005	Y/W	57	1.994	EFSR			MAN
3D9.1BF0EE6684	1999	M	321	370	Y/W	61		EFSR			MAN
3D9.1BF0ED439B	1999	M	432	1167	Y/W	63	1.934	EFSR			MAN
3D9.1BF0ED3151	1999	M	376	758	Y/W	65		EFSR			MAN
3D9.1BF0EC520A	1999	M	416	1085	Y/W	73	1.914	EFSR			MAN
3D9.1BF0ED4594	1999	F	432	1245	Y/W	78	1.435	EFSR			MAN
3D9.1BF0ED4224	1999	UNK	327	478	Y/W	80		EFSR			MAN
3D9.1BF0ED45EF	1999	F	423	1094	Y/W	86		EFSR			MAN
3D9.1BF0ED2CDD	1999	M	233	155	Y/W	90		EFSR			MAN
3D9.1BF0EE64B5	1999	M	345	540	Y/W	91		EFSR			MAN
3D9.1BF0ED4C26	1999	M	438	1313	Y/W	94	1.624	EFSR			MAN
515F533208	1997	F	620	3272	B/W	11		WFYF	L	T	EAG
3D9.1BF0ED3184	1998	UNK	555	2870	O/W	58		WFYF	S	C	EAG
3D9.1BF0ED3808	1998	UNK	555	2970	O/W	60		WFYF	S	C	EAG
3D9.1BF0EE6751	1998	UNK			O/W	76		WFYF			EAG
3D9.1BF0EC45F3	1998	F	458	1465	O/W	77		WFYF	S	C	EAG
3D9.1BF0ED4B8C	1998	UNK			O/W	89		WFYF			EAG
3D9.1BF0EC3FAF	1998	UNK	620	4195	Y/W	59	1.112	WFYF	L	T	EAG
3D9.1BF0ED3100	1999	UNK		1613	W/W	38		WFYF			EAG
3D9.1BF0EC3333	1999	UNK		1652	W/W	42		WFYF			EAG
3D9.1BF0DF22E3	1999	UNK		2143	W/W	44		WFYF			EAG
3D9.1BF0EC5204	1999	UNK		1554	W/W	47		WFYF			EAG
3D9.1BF11AE803	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AD587	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AEF44	2000	M		100	R/R			WFYF			EAG
3D9.1BF11ADFA9	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AEBA9	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AAE2F	2000	M		100	R/R			WFYF			EAG
3D9.1BF11ADE7E	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AE639	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AF287	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AE021	2000	M		100	R/R			WFYF			EAG
3D9.1BF11ADC65	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AE3A9	2000	M		100	R/R			WFYF			EAG
3D9.1BF11AE136	2000	M		200	R/R			WFYF			EAG

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Appendix C. Continued.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
3D9.1BF11AE630	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AABAC	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE425	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AEB14	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AEE04	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AF4DF	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE1A4	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AF15C	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AF6F8	2000	M		200	R/R			WFYF			EAG
3D9.1BF11EA0DC	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE699	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AF373	2000	M		200	R/R			WFYF			EAG
3D9.1BF11ADFDE	2000	M		200	R/R			WFYF			EAG
3D9.1BF11ADE4B	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE884	2000	M		200	R/R			WFYF			EAG
3D9.1BF11B0316	2000	M		200	R/R			WFYF			EAG
3D9.1BF11ADEFC	2000	M		200	R/R			WFYF			EAG
3D9.1BF11B03E9	2000	M		200	R/R			WFYF			EAG
3D9.1BF11E972C	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE278	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AEBC8	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AFE45	2000	M		200	R/R			WFYF			EAG
3D9.1BF11ADB63	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE54E	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AF16B	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE5E4	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE840	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE6DD	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AE7F2	2000	M		200	R/R			WFYF			EAG
3D9.1BF11ADF42	2000	M		200	R/R			WFYF			EAG
3D9.1BF11B055E	2000	M		200	R/R			WFYF			EAG
3D9.1BF11ADFAF	2000	M		200	R/R			WFYF			EAG
3D9.1BF11AFFBD	2000	M		300	R/R			WFYF			EAG
NOTAG1	2000	M		165	R/R			WFYF			EAG
NOTAG2	2000	M		177	R/R			WFYF			EAG
NOTAG3	2000	M		206	R/R			WFYF			EAG
NOTAG4	2000	M		97	R/R			WFYF			EAG
NOTAG5	2000	M		68	R/R			WFYF			EAG
NOTAG6	2000	M		53	R/R			WFYF			EAG
NOTAG7	2000	M		106	R/R			WFYF			EAG
NOTAG8	2000	M		111	R/R			WFYF			EAG
NOTAG9	2000	M		237	R/R			WFYF			EAG
NOTAG10	2000	M		204	R/R			WFYF			EAG

Appendix C. Continued.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
51602B4823	1997	F	512	1884	B/W	2		WFYF	S	T	MAN
515B45455A	1997	F	598	3350	B/W	12		WFYF	L	T	MAN
515B71163D	1997	F	485	1433	B/W	14		WFYF	S	T	MAN
515B4C2440	1997	F	608	3323	B/W	15		WFYF	L	T	MAN
5160285765	1997	F	590	2594	B/W	21	1.854	WFYF	L	T	MAN
515B4B7216	1997	F	503	2170	B/W	23		WFYF	S	T	MAN
515B46471D	1997	F	455	1295	B/W	26		WFYF	S	T	MAN
515B500557	1997	F	538	1753	B/W	29		WFYF	S	T	MAN
515B414F24	1997	F	551	2274	B/W	32		WFYF	S	T	MAN
51603C784D	1997	F	495	1999	B/W	33		WFYF	S	T	MAN
515D414921	1997	F	593	3253	B/W	35		WFYF	L	T	MAN
515B4E720E	1997	F	496	1745	O/Y	3		WFYF	S	C	MAN
515B431E67	1997	F	482	1600	O/Y	7		WFYF	S	C	MAN
51602B4B34	1997	F	533	2173	O/Y	21		WFYF	S	C	MAN
51602E4653	1997	F	607	4071	O/Y	23	1.371	WFYF	L	C	MAN
515B500828	1997	F	500	1780	O/Y	28		WFYF	S	C	MAN
515B49687D	1997	F	501	2283	O/Y	29		WFYF	S	C	MAN
515B57125B	1997	F	571	3027	O/Y	31		WFYF	L	C	MAN
51606D4E07	1997	F	533	2619	O/Y	33		WFYF	L	C	MAN
5160366E2D	1997	F	506	2020	O/Y	34		WFYF	S	C	MAN
515B457404	1997	F	559	2538	O/Y	38	1.493	WFYF	L	C	MAN
515F5A0D7D	1997	F	485	1953	O/Y	39		WFYF	S	C	MAN
515D436F6B	1997	F	548	2590	O/Y	40		WFYF	L	C	MAN
515C2B2711	1997	F	453	1448	O/Y	47		WFYF	S	C	MAN
3D9.1BF0DF3E77	1998	F	489	1626	O/O	50		WFYF		LA	MAN
3D9.1BF0EC48F2	1998	F	474	1491	O/O	56		WFYF		LA	MAN
3D9.1BF0EC3F98	1998	M	518	1787	O/O	58		WFYF		LA	MAN
3D9.1BF0EC4CD0	1998	F	538	2425	O/O	59		WFYF		LA	MAN
3D9.1BF0EC5EFE	1998	F	555	3055	O/O	63		WFYF		LA	MAN
3D9.1BF0ED462F	1998	F	545	2620	O/O	67		WFYF		LA	MAN
3D9.1BF0ED339F	1998	F	466	1714	O/O	83		WFYF		LA	MAN
3D9.1BF0EC41DD	1998	F	552	2976	O/O	96		WFYF		LA	MAN
3D9.1BF0DF868F	1998	F	530	2335	O/O	97		WFYF		LA	MAN
3D9.1BF0EC45CE	1998	F	580	3109	O/W	53		WFYF	L	C	MAN
3D9.1BF0ED49F4	1998	F	595	3415	O/W	54		WFYF	L	C	MAN
3D9.1BF0EC3648	1998	F	626	4426	O/W	62		WFYF	L	C	MAN
3D9.1BF0ECFF8B	1998	M	603	3570	O/W	63		WFYF	L	C	MAN
3D9.1BF0ECCDCA	1998	F	647	4042	O/W	64	1.291	WFYF	L	C	MAN
3D9.1BF0ED4CE6	1998	F	523	2255	O/W	65		WFYF	S	C	MAN
3D9.1BF0DFE3CC	1998	M	560	2879	O/W	69		WFYF	S	C	MAN
3D9.1BF0ED3B40	1998	M	493	1758	O/W	70		WFYF	S	C	MAN
3D9.1BF0EC5554	1998	M	478	1825	O/W	71		WFYF	S	C	MAN
3D9.1BF0ED3666	1998	F	611	3333	O/W	73		WFYF	L	C	MAN

Appendix C. Continued.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
3D9.1BF0EC4C18	1998	F	595	3937	O/W	80		WFYF	L	C	MAN
3D9.1BF0ECD410	1998	M	580	3266	O/W	81	1.782	WFYF	L	C	MAN
3D9.1BF0EE332F	1998	F	584	3417	O/W	82		WFYF	L	C	MAN
3D9.1BF0ECD3AA	1998	F	495	1932	O/W	86		WFYF	S	C	MAN
3D9.1BF0ED27D2	1998	F	611	4100	O/W	87		WFYF	L	C	MAN
3D9.1BF0E0E169	1998	M	505	2183	O/W	88		WFYF	S	C	MAN
3D9.1BF0ED522F	1998	F	635	4156	O/W	93	1.471	WFYF	L	C	MAN
3D9.1BF0E12278	1998	M	536	2318	O/W	95		WFYF	S	C	MAN
3D9.1BF0EC49A0	1998	F	603	4377	O/W	97		WFYF	L	C	MAN
3D9.1BF0DFA26D	1998	F	615	3761	O/W	98		WFYF	L	C	MAN
3D9.1BF0EC5764	1998	M	481	1586	Y/W	50		WFYF	S	T	MAN
3D9.1BF0DF410A	1998	F			Y/W	51		WFYF			MAN
3D9.1BF0DF853C	1998	F	533	3345	Y/W	53		WFYF	L	T	MAN
3D9.1BF0EC49B9	1998	F	600	3570	Y/W	55		WFYF	L	T	MAN
3D9.1BF0EE0FAE	1998	M	563	3497	Y/W	62		WFYF	L	T	MAN
3D9.1BF0E119C9	1998	F	508	2020	Y/W	67	1.824	WFYF	S	T	MAN
3D9.1BF0ECE5DF	1998	F	581	3295	Y/W	72		WFYF	L	T	MAN
3D9.1BF0EC47E0	1998	F	655	4813	Y/W	74		WFYF	L	T	MAN
3D9.1BF0ECE3E3	1998	F	571	3004	Y/W	75		WFYF	S	T	MAN
3D9.1BF0E0DFE6	1998	F	568	3008	Y/W	76		WFYF	S	T	MAN
3D9.1BF0ED3820	1998	F	555	2759	Y/W	77		WFYF	S	T	MAN
3D9.1BF0ECD1F8	1998	F	613	3900	Y/W	79	1.132	WFYF	L	T	MAN
3D9.1BF0EC5FED	1998	M	580	3433	Y/W	82		WFYF	L	T	MAN
3D9.1BF0ED2DEC	1998	F	605	3705	Y/W	83		WFYF	L	T	MAN
3D9.1BF0EC5246	1998	M	502	1967	Y/W	84		WFYF	S	T	MAN
3D9.1BF0ED3BE8	1998	M	490	1825	Y/W	87		WFYF	S	T	MAN
3D9.1BF0EC455F	1998	M	443	1399	Y/W	88	1.874	WFYF	S	T	MAN
3D9.1BF0ED51B2	1998	F	622	3847	Y/W	92	1.352	WFYF	L	T	MAN
3D9.1BF0EC37A9	1998	F	620	4459	Y/W	93		WFYF	L	T	MAN
3D9.1BF0ED3F36	1998	F	616	3646	Y/W	96		WFYF	L	T	MAN
3D9.1BF0DFE720	1998	M	598	3626	Y/W	97		WFYF	L	T	MAN
3D9.1BF0DEF8E1	1999	M	330	525	O/O	81		WFYF		LA	MAN
3D9.1BF0EC4274	1999	M	357	731	P/W	0		WFYF	S	T	MAN
3D9.1BF0EC537E	1999	M	357	740	P/W	2		WFYF	S	T	MAN
3D9.1BF0DF9C97	1999	M	394	990	P/W	3		WFYF	L	T	MAN
3D9.1BF0DF1D9E	1999	M	383	833	P/W	4		WFYF	L	T	MAN
3D9.1BF0DF9DA0	1999	M	338	544	P/W	5		WFYF	S	T	MAN
3D9.1BF0EC4E46	1999	M	373	916	P/W	7		WFYF	L	T	MAN
3D9.1BF0DF170A	1999	M	356	705	P/W	11		WFYF	S	T	MAN
3D9.1BF0DF973E	1999	M	333	621	P/W	12		WFYF	S	T	MAN
3D9.1BF0EC3931	1999	M	336	623	P/W	13		WFYF	S	T	MAN
3D9.1BF0ECE1BB	1999	M	355	758	P/W	14		WFYF	S	T	MAN
3D9.1BF0ED40A0	1999	M	322	505	P/W	16		WFYF	S	T	MAN

Appendix C. Continued.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
3D9.1BF0DFA334	1999	M	353	702	P/W	17		WFYF	S	T	MAN
3D9.1BF0ED5568	1999	M	380	965	P/W	21		WFYF	L	T	MAN
3D9.1BF0E0275C	1999	M	368	712	P/W	22		WFYF	S	T	MAN
3D9.1BF0EC51F0	1999	M	353	720	P/W	23		WFYF	S	T	MAN
3D9.1BF0DEF72E	1999	M	297	444	P/W	25		WFYF	S	T	MAN
3D9.1BF0EE6F56	1999	M	358	716	P/W	26		WFYF	S	T	MAN
3D9.1BF0EC5736	1999	M	384	881	P/W	28		WFYF	L	T	MAN
3D9.1BF0EC5F4E	1999	M	368	810	P/W	29		WFYF	L	T	MAN
3D9.1BF0DF21A3	1999	M	351	736	P/W	31		WFYF	S	T	MAN
3D9.1BF0ED354E	1999	M	366	763	P/W	32		WFYF	S	T	MAN
3D9.1BF0EE3548	1999	M	382	887	P/W	33		WFYF	L	T	MAN
3D9.1BF0ED41AA	1999	M	349	737	P/W	34		WFYF	S	T	MAN
3D9.1BF0E0274D	1999	M	377	932	P/W	35		WFYF	L	T	MAN
3D9.1BF0DF259F	1999	M	357	795	P/W	36		WFYF	L	T	MAN
3D9.1BF0DF0EC1	1999	M	393	948	P/W	37		WFYF	L	T	MAN
3D9.1BF0DF1720	1999	M	387	896	P/W	38		WFYF	L	T	MAN
3D9.1BF0ECE5CB	1999	M	383	944	P/W	39		WFYF	L	T	MAN
3D9.1BF0EC31AC	1999	M	387	982	P/W	40		WFYF	L	T	MAN
3D9.1BF0DF987B	1999	M	360	780	P/W	42		WFYF	S	T	MAN
3D9.1BF0EC518F	1999	M	360	792	P/W	43		WFYF	L	T	MAN
3D9.1BF0DEFE0D	1999	M	368	857	P/W	45		WFYF	L	T	MAN
3D9.1BF0DF0D82	1999	M	358	730	P/W	46		WFYF	S	T	MAN
3D9.1BF0ED32B2	1999	M	392	997	P/W	47		WFYF	L	T	MAN
3D9.1BF0DEF62A	1999	M	341	668	P/W	49		WFYF	S	T	MAN
3D9.1BF0EC5299	1999	M	369	847	W/W	0		WFYF	L	C	MAN
3D9.1BF0DF1B90	1999	M	335	646	W/W	1		WFYF	S	C	MAN
3D9.1BF0EE7535	1999	UNK		1513	W/W	2		WFYF			MAN
3D9.1BF0ED3589	1999	UNK		1696	W/W	3		WFYF			MAN
3D9.1BF0DF1C91	1999	M	372	831	W/W	4		WFYF	L	C	MAN
3D9.1BF0DF18DA	1999	UNK		1758	W/W	5		WFYF			MAN
3D9.1BF0EE1C02	1999	M	363	835	W/W	7		WFYF	L	C	MAN
3D9.1BF0ED2520	1999	M	385	1025	W/W	10		WFYF	L	C	MAN
3D9.1BF0DF9C7B	1999	M	388	979	W/W	11		WFYF	L	C	MAN
3D9.1BF0ED4597	1999	UNK		1652	W/W	12		WFYF			MAN
3D9.1BF0ECE32D	1999	M	358	772	W/W	13		WFYF	S	C	MAN
3D9.1BF0DF12EF	1999	M	361	771	W/W	14		WFYF	S	C	MAN
3D9.1BF0EC4EA6	1999	M	379	848	W/W	16		WFYF	L	C	MAN
3D9.1BF0DF2448	1999	M	349	733	W/W	17		WFYF	S	C	MAN
3D9.1BF0EC304A	1999	M	342	593	W/W	18		WFYF	S	C	MAN
3D9.1BF0EC311B	1999	M	397	1024	W/W	19	1.662	WFYF	L	C	MAN
3D9.1BF0DF974C	1999	M	340	652	W/W	20		WFYF	S	C	MAN
3D9.1BF0ED4BB4	1999	M	357	718	W/W	21		WFYF	S	C	MAN
3D9.1BF0DF95B3	1999	UNK		601	W/W	23		WFYF			MAN

Appendix C. Continued.

PIT Code	BY	Sex	FL (mm)	WT (g)	Color	Number	Freq.	Stock	Size	Group	Rearing
3D9.1BF0DFA05A	1999	M	400	1120	W/W	24		WFYF	L	C	MAN
3D9.1BF0ED4013	1999	UNK		1499	W/W	26		WFYF			MAN
3D9.1BF0DEFFDE	1999	M	338	739	W/W	27		WFYF	S	C	MAN
3D9.1BF0DF0785	1999	M	364	805	W/W	28		WFYF	L	C	MAN
3D9.1BF0ED45DA	1999	M	385	880	W/W	29		WFYF	L	C	MAN
3D9.1BF0EC3B08	1999	M	343	695	W/W	31		WFYF	S	C	MAN
3D9.1BF0DF23FE	1999	M	382	940	W/W	32		WFYF	L	C	MAN
3D9.1BF0DFA3F7	1999	M	346	727	W/W	33		WFYF	S	C	MAN
3D9.1BF0EC391D	1999	M	373	910	W/W	34		WFYF	L	C	MAN
3D9.1BF0ED4573	1999	UNK		1591	W/W	35		WFYF			MAN
3D9.1BF0EC44CA	1999	M	353	745	W/W	37		WFYF	S	C	MAN
3D9.1BF0DFA02C	1999	M	362	794	W/W	39		WFYF	S	C	MAN
3D9.1BF0ED3F09	1999	M	358	781	W/W	40		WFYF	S	C	MAN
3D9.1BF0EC525C	1999	M	347	648	W/W	43		WFYF	S	C	MAN
3D9.1BF0DEF6F5	1999	M	345	689	W/W	45		WFYF	S	C	MAN
3D9.1BF0EC5D76	1999	M	357	795	W/W	46		WFYF	L	C	MAN
3D9.1BF0ECD102	1999	M	375	873	W/W	48		WFYF	L	C	MAN
3D9.1BF0DF9BAB	1999	M	341	597	W/W	49		WFYF	S	C	MAN
NOTAG3				—	Y/W	81		WFYF		T	MAN
NOTAG1				—	O/Y	35					MAN
NOTAG2				—	Y/W	71					MAN

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